# REPORT No. 91

## NOMENCLATURE FOR AERONAUTICS

IN THREE PARTS

BY NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

# INTRODUCTION.

The following nomenclature and list of symbols were approved by the Executive Committee of the National Advisory Committee for Aeronautics, for publication as a technical report on April 1, 1920, on recommendation of the Subcommittee on Aerodynamics.

The purpose of the committee in the preparation and publication of this report is to secure uniformity in the official documents of the Government and, as far as possible, in technical and other commercial publications. This report supersedes all previous publications of the committee on this subject.

The Subcommittee on Aerodynamics had charge of the preparation of the report. It was materially assisted by an Interdepartmental Conference on Aeronautical Nomenclature and Symbols, organized by the Executive Committee, with the approval of the War and Navy Departments, for the purpose of giving adequate representation to the divisions of the Army Air Service and to the bureaus of the Navy Department most concerned. The first meeting of the interdepartmental conference was held on October 23, 1919, and the second meeting on January 15, 1920, at which meeting this report was unanimously approved and recommended to the Subcommittee on Aerodynamics, with the reservation that stability terms and power-plant terms be given further and special consideration.

The stability terms were accordingly referred for special consideration to Messrs. E. B. Wilson, J. C. Hunsaker, A. F. Zahm, E. P. Warner, and H. Bateman, and the power-plant terms were referred to the Subcommittee on Power plants for Aircraft. The complete report was adopted by the Subcommittee on Aerodynamics on March 8, 1920, and recommended to the Executive Committee for approval and publication. The personnel of the two organizations primarily concerned with the preparation of this report follows.

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# REPORT No. 91.

## NOMENCLATURE FOR AERONAUTICS.

By the National Advisory Committee for Aeronautics.

### PART I.

### NOMENCLATURE BY DIVISIONS.

#### AIRCRAFT.

A. TYPES OF AIRCRAFT.

AEROSTAT.—An aircraft which embodies a container filled with a gas lighter than air and which is sustained by the buoyancy of this gas; e. g., airship, balloon.

AIRCRAFT.—Any form of craft designed for the navigation of the air—airplanes, airships, balloons, helicopters, kites, kite balloons, ornithopters, gliders, etc.

AIRPLANE.—A form of aircraft heavier than air which obtains support by the dynamic reaction of the air against the wings and which is driven through the air by a screw propeller. This term is commonly used in a more restricted sense to refer to airplanes fitted with landing gear suited to operation from the land. If the landing gear is suited to operation from the water, the term "seaplane" is used. (See definition.)

AIRSHIP.—A form of aerostat provided with a propelling system and with means of controlling the direction of movement.

BALLOON.—A form of aerostat deriving its support in the air from the bouyancy of the air displaced by an envelope, the form of which is maintained by the pressure of a contained gas lighter than air, and having no power plant or means of controlling the direction of flight in the horizontal plane.

GLIDER.—A form of aircraft similar to an airplane, but without any power plant. Gliders are used chiefly for sport.

HELICOPTER.—A form of aircraft whose support in the air is derived from the vertical thrust of propellers.

KITE.—A form of aircraft without other propelling means than the towline pull, whose support is derived from the force of the wind moving past its surface.

ORNITHOPTER.—A form of aircraft deriving its support and propelling force from flapping wings.

PARACHUTE.—An apparatus used to retard the descent of a falling body by offering resistance to motion through the air; usually made of light fabric with no rigid parts.

#### AEROSTATS.

B. TYPES OF AEROSTATS.

AIRSHIP:

Nonrigid.—An airship whose form is maintained by the pressure of the contained gas.

Rigid.—An airship whose form is maintained by a rigid structure contained within the envelope.

Semirigid.—An airship whose form is maintained by means of a rigid or jointed keel and by gas pressure.

BALLOON:

Barrage.—A small captive balloon, raised as a protection against attacks by airplanes.

Captive.—A balloon restrained from free flight by means of a cable attaching it to the earth.

B. TYPES OF AREOSTATS—Continued.

BALLOON—Continued.

KITE.—An elongated form of captive balloon, fitted with tail appendages to keep it headed into the wind, and usually deriving increased lift due to its axis being inclined to the wind. A Caquot balloon is of this type. (Fig. 8.)

NURSE.—A small balloon made of heavy fabric, employed as a portable means for storing gas. Sometimes one is so connected as to automatically allow for the expansion or contraction of the gas in an aerostat when on the ground.

PILOT.—A small balloon sent up to show the direction of the wind by observations of its flight with theodolites.

SOUNDING.—A small balloon sent aloft without passengers but with registering meteorological and other instruments.

## AIRPLANES.

C. TYPES OF AIRPLANES.

AIRPLANE:

PUSHER.—A term commonly applied to a single-engined airplane with the propeller in the rear of the main supporting surfaces. (Fig. 3.)

TRACTOR.—A term commonly applied to a single-engined airplane with the propeller forward of the main supporting surfaces. (Fig. 4.)

BIPLANES.—A form of airplane whose main supporting surface is divided into two parts, superimposed.

MONOPLANE.—A form of airplane which has but one main supporting surface extending equally on each side of the body.

MULTIPLANE.—A form of airplane whose main supporting surface is divided into more than four parts.

QUADRUPLANE.—A form of airplane whose main supporting surface is divided into four parts, superimposed.

SEAPLANE.—A particular form of airplane designed to rise from and land on the water.

(*a*) BOAT SEAPLANE (or flying boat).—A form of seaplane having for its central portion a boat which provides flotation. It is often provided with auxiliary floats or pontoons. (Fig. 14.)

(*b*) FLOAT SEAPLANE.—A form of seaplane in which the landing gear consists of one or more floats or pontoons. (Fig. 15.)

TANDEM.—An airplane with two or more sets of wings of substantially the same area (not including the empennage) placed one in front of the other and on about the same level.

TRIPLANE.—A form of airplane whose main supporting surface is divided into three parts, superimposed.

## GENERAL AERODYNAMICS.

D. MISCELLANEOUS TERMS.

AEROFOIL.—A winglike structure, flat or curved, designed to obtain reaction upon its surfaces from the air through which it moves.

AEROFOIL SECTION.—A section of an aerofoil made by a plane parallel to the plane of symmetry of the aerofoil and to the normal direction of motion.

ASPECT RATIO.—The ratio of span to mean chord of an aerofoil.

ATTACK, ANGLE OF.—The acute angle between the direction of the relative wind and the chord of an aerofoil; i. e., the angle between the chord of an aerofoil and its motion relative to the air. (This definition may be extended to any body having an axis.)

D. MISCELLANEOUS TERMS—Continued.

CAMBER.—The convexity or rise of the curve of an aerofoil from its chord, usually expressed as the ratio of the maximum departure of the curve from the chord to the length of the chord. "Top camber" refers to the top surface of an aerofoil, and "bottom camber" to the bottom surface; "mean camber" is the mean of these two.

CENTER OF PRESSURE OF AN AEROFOIL SECTION.—The point in the chord of an aerofoil section, prolonged if necessary, through which at any given attitude the line of action of the resultant air force passes.

CHORD (of an AEROFOIL SECTION).—The line of a straightedge brought into contact with the lower surface of the section at two points. In the case of an aerofoil having double convex camber, the straight line joining the leading and trailing edges. (These edges may be defined, for this purpose, as the two points in the section which are farthest apart.) (Fig. 9.)

LENGTH.—The length of the projection of the aerofoil section on its chord.

CRITICAL ANGLE.—The angle of attack at which the flow about an aerofoil changes abruptly, with corresponding abrupt changes in the lift and drag coefficients. An aerofoil may have two or more critical angles, one of which almost always corresponds to the angle of maximum lift.

LEADING EDGE.—The foremost edge of an aerofoil or propeller blade.

SKIN FRICTION.—The tangential component of the fluid force at a point on a surface. It depends on the viscosity and density of the fluid, the total surface area, and the roughness of the surface of the object.

STABILIZER, MECHANICAL.—A mechanical device to stabilize the motion of an aircraft. Includes gyroscopic stabilizers, pendulum stabilizers, inertia stabilizers, etc.

STREAMLINE.—The path of a small portion of a fluid, supposed continuous, commonly taken relative to a solid body with respect to which the fluid is moving. The term is commonly used only of such paths as are not eddying, but the distinction should be made clear by the context.

STREAMLINE FLOW.—The condition of continuous flow of a fluid, as distinguished from eddying flow.

STREAMLINE FORM.—A fair form intended to avoid eddying and to preserve streamline flow.

SURFACE.—An aerofoil used for sustentation or control or to increase stability. Applies to the whole member, and not to one side only.

BALANCED.—A surface, such as a rudder, aileron, etc., part of which is in front of its pivot.

TRAILING EDGE.—The rearmost edge of an aerofoil or propeller blade.

WIND TUNNEL.—An elongated inclosed chamber, including means for the production of a substantially steady air current through the chamber. Models of aircraft or other objects are supported in the center of the airstream and their resistance and other characteristics when exposed to an air current of known velocity are determined. The term includes those laboratories in which, as in the Eiffel type, there is an experimental chamber of much larger cross section than the air current.

ZERO LIFT ANGLE.—The angle between the chord and the relative wind when the lift is zero.

ZERO LIFT LINE.—The position in the plane of an aerofoil section of the line of action of the resultant air force when the position of the section is such that the lift is zero.

## E. FORCES, MOMENTS, ANGLES, AND AXES.

ATTITUDE.—The attitude of an aircraft is determined by the inclination of its axes to a "frame of reference", fixed to the earth; i. e., the attitude depends entirely on the position of the aircraft as seen by an observer on the ground.

AXES OF AN AIRCRAFT.—Three fixed lines of reference; usually centroidal and mutually rectangular. (Fig. 7.)

The principal longitudinal axis in the plane of symmetry, usually parallel to the axis of the propeller, is called the longitudinal axis; the axis perpendicular to this in the plane of symmetry is called the normal axis; and the third axis, perpendicular to the other two, is called the lateral axis. In mathematical discussions the first of these axes, drawn from front to rear, is called the $X$ axis; the second, drawn upward, the $Z$ axis; and the third, running from right to left, the $Y$ axis.

CROSS-WIND FORCE.—The component perpendicular to the lift and to the drag of the total force on an aircraft due to the air through which it moves.

DRAG.—The component parallel to the relative wind of the total force on an aerofoil or aircraft due to the air through which it moves.

In the case of an airplane, that part of the drag due to the wings is called "wing resistance"; that due to the rest of the airplane is called "structural," or "parasite resistance."

LIFT.—The component of the total air force which is perpendicular to the relative wind and in the plane of symmetry. It must be specified whether this applies to a complete aircraft or parts thereof. (In the case of an airship this is often called "dynamic lift.")

PITCH, ANGLE OF.—The angle between two planes defined as follows: One plane includes the lateral axis of the aircraft and the direction of the relative wind; the other plane includes the lateral axis and the longitudinal axis. (In normal flight the angle of pitch is, then, the angle between the longitudinal axis and the direction of the relative wind.) This angle is denoted by $\theta$, and is positive when the nose of the aircraft rises.

ROLL, ANGLE OF, or BANK, ANGLE OF.—The angle through which an aircraft must be rotated about its longitudinal axis in order to bring its lateral axis into a horizontal plane. This angle is denoted by $\phi$.

YAW:

ANGLE OF.—The angle between the direction of the relative wind and the plane of symmetry of an aircraft. This angle is denoted by $\psi$, and is positive when the aircraft turns to the right.

YAWING.—Angular motion about the normal axis.

## F. PERFORMANCE AND CONDITIONS OF FLIGHT.

CEILING:

ABSOLUTE.—The maximum height above sea level which a given aircraft can approach asymptotically, assuming standard air conditions.

SERVICE.—The height above sea level at which a given aircraft ceases to rise at a rate higher than a small specified one (100 feet per minute in United States Air Service). This specified rate may be different in the services of different countries.

DRIFT.—The angular deviation from a set course over the earth, due to cross currents of wind; hence, "drift meter."

DYNAMIC FACTOR.—The ratio between the load carried by any part of an aircraft when accelerating or when otherwise subjected to abnormal conditions and the load carried in normal flight.

FACTOR OF SAFETY.—The ratio of the ultimate strength of a member to the maximum possible load occurring under conditions specified.

F. PERFORMANCE AND CONDITIONS OF FLIGHT—Continued.

FLIGHT PATH.—The path of the center of gravity of an aircraft with reference to the earth.

FREE-FLIGHT TESTING.—The conduct of special flight tests of a scientific nature, as contrasted with performance testing (q. v.).

LOAD:

DEAD.—The structure, power plant, and essential accessories of an aircraft. Included in this are the water in the radiator, tachometer, thermometer, gauges, air-speed indicators, levels, altimeter, compass, watch and hand starter, and also, in the case of an aerostat, the amount of ballast which must be carried to assist in making a safe landing.

FULL.—The total weight of an aircraft when loaded to the maximum authorized loading of that particular type.

USEFUL.—The excess of the full load over the dead load of the aircraft itself. Therefore useful load includes the crew and passengers, oil and fuel, ballast, electric-light installation, chart board, detachable gun mounts, bomb storage and releasing gear, wireless apparatus, etc.

LOAD FACTOR.—The ratio of the ultimate strength of a member to the load under horizontal steady rectilinear flight conditions.

MARGIN OF POWER.—The difference between the power available at any given speed and in air of given density and the power required for level flight under the same conditions. The best rate of climb at any altitude depends on the maximum margin of power.

MINIMUM SPEED.—The lowest speed which can be maintained in level flight, with any throttle setting whatever.

PERFORMANCE.—The maximum and minimum speeds and rate of climb at various altitudes, the time to climb to these altitudes, and the ceiling constitute the performance characteristics of an airplane. *Performance testing* is the process of determining these quantities.

POWER LOADING.—The weight per horsepower, computed on a basis of full load and of power in air of standard density, unless otherwise stated.

RATE OF CLIMB.—The vertical component of the air speed of an aircraft; i. e., its vertical velocity with reference to the air.

RELATIVE WIND.—The motion of the air with reference to a moving body. Its direction and velocity, therefore, are found by adding two vectors, one being the velocity of the air with reference to the earth, the other being equal and opposite to the velocity of the body with reference to the earth.

RUDDER TORQUE.—The twisting effect exerted by the rudder on the fuselage, due to the relative displacement of the center of pressure of the rudder. The product of the rudder area by the distance from its center of area to the center line of the fuselage may be used as a relative measure of rudder torque.

SPEED:

AIR.—The speed of an aircraft relative to the air.

GROUND.—The horizontal component of the velocity of an aircraft relative to the earth.

G. MATERIALS.

CORD.—A species of wire made up of several strands (usually 7) twisted together as in a rope, each of the strands, in turn, being made up of several (usually 19) individual wires.

DOPE, AIRPLANE.—A general term applied to the material used in treating the cloth surface of airplane members to increase strength, produce tautness, and act as a filler to maintain air-tightness.

G. MATERIALS—Continued.

LAMINATED WOOD.—Wooden parts made up by gluing or otherwise fastening together individual wood planks or laminations with the grain substantially parallel.

PLYWOOD.—A product formed by gluing together two or more layers of wood veneer.

STRAND.—A species of wire made up of several individual wires twisted together. (There are usually 19 wires; a single wire as core, and inner layer of 6 wires, and an outer layer of 12.)

VENEER.—Thin sheets or strips of wood.

WIRE.—In aeronautics refers specifically to hard-drawn solid wire.

H. GENERAL CONSTRUCTIONAL TERMS.

FAIRING.—A member whose primary function is to produce a smooth outline and to reduce head resistance or drag.

FITTING.—A generic term for any small metal part used in the structure of an airplane.

INSPECTION WINDOW.—A small transparent window in the envelope of a balloon or in the wing of an airplane to allow inspection of the interior.

SPLICE (of a wooden member).—A joint of two or more pieces of wood in which one piece overlaps the other in such a manner as to maintain the strength.

STAY.—A wire or other tension member. For example, the stays of the wing and body trussing.

STRUT.—A member of a truss frame designed to carry compressive loads. For instance, the vertical members of the wing truss of a biplane (interplane struts) and the short vertical and horizontal member separating the longerons (q. v.) in the fuselage. (Figs. 1 and 12.)

I. CONTROLS.

AILERON.—A hinged or pivoted movable auxiliary surface of an airplane, usually part of the trailing edge of a wing, the primary function of which is to impress a rolling moment on the airplane. (Fig. 1.)

CONTROLS.—A general term applying to the means provided to enable the pilot to control the speed, direction of flight, attitude and power of an aircraft.

CONTROL COLUMN, or YOKE.—A control lever with a rotatable wheel mounted at its upper end. (*See* Control stick.) Pitching is controlled by fore-and-aft movement of the column; rolling by rotation of the wheel. "Wheel control" is that type of control in which such a column or yoke is used.

CONTROL STICK.—The vertical lever by means of which certain of the principal controls of an airplane are operated. Pitching is controlled by a fore-and-aft movement of the stick, rolling by a side-to-side movement. "Stick control" is that type of control in which such a stick is used.

ELEVATOR.—A movable auxiliary surface of an airplane, usually attached to the tail plane, the function of which is to impress a pitching moment on the aircraft. (Fig. 10.)

HORN.—The operating lever of a control surface of an aircraft; e. g., aileron horn, rudder horn, elevator horn.

RUDDER.—A hinged or pivoted surface used for the purpose of impressing yawing moments on an aircraft; i. e., for controlling its direction of flight. (Fig. 10.)

RUDDER BAR.—The foot bar by means of which the rudder is operated.

J. PROPELLER TERMS.

ASPECT RATIO OF PROPELLERS.—The ratio of propeller diameter to maximum blade width.

BLADE BACK.—The markedly convex surface of a propeller blade which corresponds to the upper surface of an aerofoil.

J. PROPELLER TERMS—Continued.

BLADE FACE.—The surface of a propeller blade, flat or slightly cambered near the tips, which corresponds to the lower surface of an aerofoil.

BLADE SETTING, ANGLE OF.—The angle which the chord of a propeller section makes with a plane perpendicular to the axis of the propeller. This angle varies along the blade, increasing as the boss is approached.

BLADE WIDTH RATIO.—The ratio of the width of a propeller blade at any point to the circumference of the circle along which that point travels when the propeller is rotating and the airplane is held stationary. When used without qualifying terms, it refers to the ratio of the maximum blade width to the circumference of the circle swept by the propeller.

TOTAL WIDTH RATIO.—The product of blade width ratio by number of blades.

BOSS.—The central portion of an air screw. The portion in which the hub is mounted.

CAMBER RATIO.—The ratio of the maximum ordinate of a propeller section to its chord.

DISK AREA.—The total area swept by a propeller; i. e., the area of a circle having a diameter equal to the propeller diameter.

INDRAFT.—The drawing in of air from in front of a propeller by the action of the rotating blades. The indraught velocity relative to the propeller is somewhat higher than that of the undisturbed air at most points of the propeller disk.

PITCH:

(*a*) PITCH, AERODYNAMIC.—The distance a propeller would have to advance in one revolution in order that the torque might be zero.

(*b*) PITCH, EFFECTIVE.—The distance an aircraft advances along its flight path for one revolution of the propeller.

(*c*) PITCH, GEOMETRICAL.—The distance an element of a propeller would advance in one revolution if it were turning in a solid nut; i. e., if it were moving along a helix of slope equal to the angle between the chord of the element and a plane perpendicular to the propeller axis. The mean geometrical pitch of a propeller, which is a quantity commonly used in specifications, is the mean of the geometrical pitches of the several elements.

(*d*) PITCH, STANDARD.—The "pitch of a propeller" is usually stated as the geometrical pitch taken at two-thirds of the radius.

(*e*) PITCH, VIRTUAL.—The distance a propeller would have to advance in one revolution in order that there might be no thrust.

(*f*) PITCH SPEED.—The product of the mean geometrical pitch by the number of revolutions of the propeller in unit time; i. e., the speed the aircraft would make if there were no slip.

(*g*) SLIP.—The difference between the effective pitch and the mean geometrical pitch. Slip is usually expressed as a percentage of the mean geometrica pitch.

PUSHER PROPELLER.—A propeller which is placed at the rear end of its shaft and pushes against the thrust bearing.

RACE ROTATION.—The rotation of the air influenced by a propeller. This rotation is much more marked in the slip-stream than in front of the propeller.

RAKE, BLADE.—The angle which the line joining the centroids of the sections of a propeller blade makes with a plane perpedicular to the propeller shaft. The rake is positive when the blades are thrown forward.

SLIP, OF PROPELLER. [*See* Pitch (*g*).]

SLIP STREAM.—The stream of air behind a propeller.

STATIC THRUST.—The thrust developed by a propeller when the aircraft is held stationary on the ground.

TRACTOR PROPELLER.—A propeller which is placed at the forward end of its shaft and pulls on the thrust bearing.

J. PROPELLER TERMS—Continued.

WINDMILL.—A small air-driven turbine with blades similar to those of a propeller exposed on an aircraft, usually in the slip-stream, and used to drive such auxiliary apparatus as gasoline pumps and radio generators.

K. INSTRUMENTS.

AIR-SPEED INDICATOR.—An anemometer mounted on an aircraft for the purpose of indicating the speed of the aircraft.

TRUE AIR-SPEED INDICATOR.—An instrument, usually working on the principle of the Biram or Robinson anemometers, which gives the true air speed, independent of density.

APPARENT AIR-SPEED INDICATOR.—An instrument, usually dependent on pressure measurements, the readings of which vary with the density of the air.

ALTIMETER.—An aneroid barometer, mounted on an aircraft, whose dial is marked in feet, yards, or meters.

ANEMOMETER.—Any instrument for measuring the velocity or force of the wind.

BAROGRAPH.—An instrument used to make a permanent record of variations in barometric pressure. In aeronautics the charts on which the records are made sometimes indicate altitudes directly instead of barometric pressures.

DRIFT METER.—An instrument for the measurement of the angular deviation of an aircraft from a set course, due to cross winds.

INCLINOMETER:

RELATIVE.—An instrument giving the attitude of an aircraft with reference to apparent gravity. Such instruments are sometimes incorrectly referred to as banking indicators.

ABSOLUTE.—An instrument giving the attitude of an aircraft with reference to true gravity.

PITOT TUBE.—A tube with an end open square to a fluid stream. It is exposed with the open end pointing upstream to detect an impact pressure. It is usually associated with a coaxial tube surrounding it, having perforations normal to the axis for indicating static pressure; or there is such a tube placed near it and parallel to it, with a closed conical end and having perforations in its side. The velocity of the fluid can be determined from the difference between the impact pressure and the static pressure, as read by a suitable gauge. This instrument is often used to determine the velocity of an aircraft through the air. (Fig. 13.)

PRESSURE NOZZLE.—The apparatus which, in combination with a gauge, is used to measure the pressure due to speed through the air. Includes both Pitot and Venturi tubes. Pressure nozzles of various types are also used in yawmeters and other instruments.

RATE-OF-CLIMB INDICATOR.—An instrument indicating the vertical component of velocity of an aircraft. Most rate-of-climb meters depend on the rate of change of the atmospheric pressure.

STATOSCOPE.—An instrument to detect the existence of minute changes of atmospheric pressure, and so of small vertical motions of an aircraft.

TURN INDICATOR.—An instrument showing when the direction of the line of flight, or the direction of the projection of that line on a horizontal plane, is altering, and, in its more refined forms, giving the rate of turn, in terms either of the angular velocity or of the radius of curvature.

VENTURI TUBE.—A short tube with flaring ends and a constriction between them, so that, when fluid flows through it, there will be a suction produced in a side tube opening into the constricted throat. This tube, when combined with a Pitot tube or with one giving static pressure, forms a pressure nozzle, which may be used as an instrument to determine the speed of an aircraft through the air. (Fig. 21.)

YAWMETER.—An instrument giving by direct reading the angle of yaw.

## AEROSTATICS.

### L. AEROSTATIC TERMS.

AERONAUT.—The pilot of an aerostat.

AEROSTATICS.—The science which relates to the buoyancy and behavior of lighter-than-air craft.

AEROSTATION.—The operation of balloons and airships. Corresponds to aviation (q. v.), but refers to lighter-than-air craft.

APPARENT PRESSURE.—The excess of pressure inside the envelope of an aerostat over the atmospheric pressure. In the case of an airship, the excess of pressure is measured at the bottom of the envelope unless otherwise specified.

BUOYANCY.—The upward force exerted on a lighter-than-air craft due to the air which it displaces.

CENTER OF.—The center of volume of the gas container (envelope) or the center of gravity of a gas of a balloon or airship.

POSITIVE AND NEGATIVE.—The positive or negative difference between the buoyancy and the weight of a balloon or airship. The unbalanced force which causes ascent or descent.

CAPACITY.—The cubic contents or volume of an aerostat.

DISCHARGEABLE WEIGHT.—The excess of the gross buoyancy over the dead load, the crew, and such items of equipment as are essential to enable an airship to fly and land safely.

GROSS BUOYANCY.—The total upward force on an aerostat at rest; the total volume multiplied by the difference of density of the air and the contained gas.

PERMEABILITY.—The measure of the rate of diffusion of gas through intact balloon fabric; usually expressed in cubic meters per square meter per 24 hours.

PURITY OF A GAS.—The percentage, by number of molecules, of the light gas used for inflation, such as hydrogen, to all the gases within the container.

TAIL DROOP.—A deformation of the airship in which the axis bends downward at the after end.

### M. PARTS OF AEROSTATS.

AIR SCOOP.—A projecting cowl, which, by using the dynamic pressure of the relative wind or slipstream, serves to maintain air pressure in the interior of the ballonet of an aerostat. (Fig. 2.)

APPENDIX.—The tube at the bottom of a balloon, used for inflation. In the case of a spherical balloon it also serves to increase the "head" of gas, and so to build up an internal pressure sufficient to keep the envelope from being pulled out of shape by the weight of the basket. (Fig. 6.)

AUTOMATIC VALVE.—An automatic escape and safety valve for the purpose of regulating internal pressure in an aerostat.

BALLONET.—A small balloon within the interior of a balloon or airship for the purpose of controlling the ascent or descent and for maintaining pressure on the outer envelope so as to prevent deformation. The ballonet is kept inflated with air at the required pressure, under the control of valves, by a blower or by the action of the wind caught in an air scoop.

BALLOON BED.—A mooring place on the ground for a captive balloon.

BALLOON FABRIC.—The finished material, usually rubberized, of which balloon or airship envelopes are made.

BIASED.—Plied fabric in which the threads of the plies are at an angle to each other.

PARALLEL.—Plied fabric in which the threads of the plies are parallel to each other.

BASKET.—The car suspended beneath a balloon, for passengers, ballast, etc.

M. PARTS OF AEROSTATS—Continued.

BONNET.—The appliance, having the form of a parasol, which protects the valve of a spherical balloon against rain.

BOW STIFFENERS.—Rigid members attached to the bow of a nonrigid or semirigid envelope to reinforce it against the pressure caused by the motion of the airship. (Sometimes called nose stiffeners.)

BRIDLE.—A sling of cordage which has its ends attached to the envelope of a balloon or airship and a rope or cable running from an intermediate point.

CAR.—The nacelle of an airship.

CONCENTRATION RING:

(*a*) FREE BALLOON.—A hoop to which are attached the ropes suspending the basket and to which the net is also secured.

(*b*) PARACHUTE.—A hoop to which the rigging of the parachute is attached and also the line sustaining the passenger.

(*c*) AIRSHIP.—A metal ring to which several rigging lines are brought from the envelope and from which one or more lines also lead to the car.

CROW'S-FOOT.—A system of diverging short ropes for distributing the pull of a single rope.

DRAG ROPE.—The rope dropped by an airship in order to allow it to be secured by a landing party.

DRIP FLAP.—A strip of fabric attached by one edge to the envelope of an aerostat so that rain runs off its free edge instead of dripping into the basket or car. The drip flap assists also to keep the suspension ropes dry and nonconducting.

ENVELOPE.—The outer covering of a rigid airship; or, in the case of a balloon or a nonrigid airship, the bag which contains the gas.

EQUATOR.—The largest horizontal circle of a spherical balloon.

FINS (KITE BALLOON).—The air-inflated lobes intended to keep the balloon headed into the wind.

GORE.—The portion of the envelope of a balloon or airship included between two adjacent meridian seams.

GROUND CLOTH.—Canvas placed on the ground to protect a balloon.

HOG (AIRSHIP).—A distortion of the envelope in which the axis becomes convex upward or both ends droop.

HULL.—The main structure of a rigid airship, consisting of a covered elongated framework which incloses the gas bags and which supports the cars and equipment.

JACKSTAY.—A longitudinal rigging provided to maintain the correct distance between the heads of various riggings on an airship.

KEEL.—A member or assembly of members which provides longitudinal strength to an airship of rigid or semirigid type. In the case of a rigid airship the keel is usually an elaborately trussed girder and may be inclosed within the envelope or may project beyond (usually below) the regular cross-sectional form of the envelope.

ARTICULATED.—A keel made up of a series of members hinged together at their ends.

LOBES.—Inflated bags at the stern of an elongated balloon, designed to give it directional stability. Also used to denote the sections into which the envelope is sometimes (e. g., in the Astra-Torres) divided by the tension of the internal rigging.

MOORING HARNESS.—The system of bands of tape over the top of a balloon to which are attached the mooring ropes.

NET.—A rigging made of ropes and twine on spherical balloons which supports the weight of the basket, etc., distributing the load over the entire upper surface of the envelope.

NOSE CAP.—A cap used to reinforce the bow stiffeners of an airship.

PANEL.—The unit piece of fabric of which the envelope of an aerostat is made.

M. PARTS OF AEROSTATS—Continued.

PATCH.—A strengthened or reinforced flap of fabric, of variable form, according to the maker, which is cemented to the envelope and forms an anchor by which some portion of the machine is attached to the envelope. (Fig. 2.)

PROOFING.—Material applied to the fabric of an aerostat at the time of manufacture, to protect it against weather or to prevent the passage of gas.

RIP CORD.—The rope running from the rip panel of a balloon or nonrigid airship to the basket, the pulling of which tears off the rip panel and causes immediate deflation.

RIP PANEL.—A strip in the upper part of a balloon or nonrigid airship which is torn off when immediate deflation is desired.

SAFETY LOOP.—A loop formed immediately outside the conical reversing bag through which the valve rope emerges from the bottom of an aerostat. Before the automatic valve can be opened by the aid of the valve rope the fastening of this safety loop is torn off by a strong pull on the valve rope from the nacelle.

SERPENT.—A short, heavy trail rope.

SUSPENSION BAND.—The band around a balloon or airship to which are attached the main bridle suspensions of the basket or car.

SUSPENSION BAR.—The bar used for the concentration of basket suspension ropes in captive balloons.

TAIL CUPS.—A steadying device attached by lines at the rear of certain types of elongated captive balloons. Somewhat similar to a sea anchor. (Fig. 17.)

TRAIL ROPE.—The long trailing rope attached to a spherical balloon to serve as a brake and as a variable ballast.

TOGGLE.—A short crossbar of wood or metal, having a shouldered groove, which is fitted at the end of a rope at right angles to it. It is used for obtaining a quickly detachable connection with an eye at the end of another rope. (Fig. 18.)

TRAJECTORY BAND.—A band of webbing carried in a curve over the top of the envelope of an airship to distribute the stresses due to the suspension. The use of trajectory bands was introduced in the Parseval airships. (Fig. 19.)

## TERMS LIMITED TO AIRPLANES.

N. WING PARTS.

ANTIDRAG WIRES.—Wires designed primarily to resist forces acting parallel to the planes of the wings of an airplane and in the same direction as the direction of flight.

ANTILIFT WIRES.—Wires in an airplane intended mainly to resist forces in the opposite direction to the lift, and to oppose the lift wires and prevent distortion of the structure by overtightening of those members.

BAY.—The cubic section of a truss included between two transversely adjacent sets of struts of an airplane. The first bay is the one closest to the plane of symmetry.

CABANE.—A pyramidal or prismoidal framework to which wire or cable stays are secured.

CELL.—The entire structure of the wings and wing trussing on one side of the fuselage of an airplane, or between fuselages or nacelles, where there are more than one.

DRAG STRUT.—A compression member of the internal bracing system of an aerofoil.

DRAG WIRES.—All wires designed primarily to resist forces acting parallel to the planes of the wings of an airplane and opposite to the direction of flight.

INTERNAL DRAG WIRES are concealed inside the wings.

EXTERNAL DRAG WIRES run from the wing cell to the nose of the fuselage or some other part of the machine.

KING POST.—The main compression member of a trussing system applied to a member subject to bending. (Fig. 4.)

N. WING PARTS—Continued.

LIFT WIRES.—The wires which transmit the lift on the outer portion of the wings of an airplane in toward the fuselage or nacelle. These wires usually run from the top of an interplane strut to the bottom of the strut next nearer the fuselage.

MAIN SUPPORTING SURFACE.—A pair of wings, extending on the same level from tip to tip of an airplane; e. g., a triplane has three main supporting surfaces. The main supporting surfaces do not include any surfaces intended primarily for control or stabilizing purposes.

PANEL.—A portion of a wing of an airplane which is constructed entirely separate from the rest of the wing, and which is attached to the remainder by bolts and fittings.

PHILLIPS' ENTRY.—A reversal of curvature of the lower surface of an aerofoil near the leading edge. The result is to decrease the drag and provide more depth for the front spar. (Fig. 9.)

STAGGER WIRES.—Wires connecting the upper and lower main supporting surfaces of an airplane, and lying in planes substantially parallel to the plane of symmetry.

WING.—The portion of a main supporting surface of an airplane on one side of the plane of symmetry; e. g., a biplane has four wings.

WING RIB.—A fore-and-aft member of the wing structure of an airplane, used to give the wing section its form and to transmit the load from the fabric to the spars. (Fig. 20.)

RIB, COMPRESSION.—A heavy rib designed to have the above functions and also to act as a strut opposing the pull of the wires in the internal drag truss. (Fig. 20.)

RIB, FORM.—An incomplete rib, frequently consisting only of a strip of wood extending from the leading edge to the front spar, which is used to assist in maintaining the form of the wing where the curvature of the aerofoil section is sharpest. (Fig. 20.)

WING SPARS.—The principal transverse structural elements of the wing assembly of an airplane. The load is transmitted from the ribs to the spars, and thence to the lift and drag trusses. (Fig. 20.)

WING TRUSS.—The framing by which the wing loads of an airplane are transmitted to the fuselage; comprises struts, wires, or tie-rods, and spars.

O. FUSELAGE AND NACELLE PARTS.

BULKHEAD.—A transverse structural member of a fuselage or nacelle, continuous around the periphery.

COCKPIT.—The open space in which the pilot and passengers are accommodated. A cockpit is never completely housed in.

COWLING.—The metal covering which houses the engine, and sometimes a portion of the fuselage or nacelle as well.

FIRE WALL.—A metal plane, so set as to isolate from the engine the other parts of the airplane structure, and so to reduce the risk from a backfire.

FUSELAGE.—The elongated structure, of approximately streamline form, to which are attached the wings and tail unit of an airplane. In general it is designed to hold the passengers.

LONGERON.—A fore-and-aft member of the framing of an airplane fuselage or nacelle, usually continuous across a number of points of support. (Fig. 12.)

MONOCOQUE.—A type of fuselage which is constructed by wrapping strips of veneer around formers, and in which the veneer is primarily depended on to carry stresses arising in the fuselage.

NACELLE.—The inclosed shelter for passengers or for a power plant. A nacelle is usually shorter than a fuselage and does not carry the tail unit.

O. FUSELAGE AND NACELLE PARTS—Continued.

SHUTTERS.—The adjustable blinds or vanes which are used to control the amount of air flowing through the radiator and so to regulate the temperature of the cooling water.

SPINNER.—A fairing, usually made of sheet metal and roughly conical or paraboloid in form, which is attached to the propeller boss and revolves with it.

STATION.—A term used to denote the location of framing attachment in a fuselage or nacelle (strut points in a trussed fuselage, bulkhead points in a veneer fuselage)

P. LANDING GEAR PARTS.

FLOAT.—A completely inclosed water-tight structure attached to an aircraft in order to furnish it buoyancy when in contact with the surface of the water. In float seaplanes the crew is carried in a fuselage or nacelle separate from the float.

FLOTATION GEAR.—An emergency landing gear attached to an airplane, which will permit of safe landing on the water and provide buoyancy when resting on the surface of the water.

HULL.—The portion of a boat seaplane which furnishes buoyancy when in contact with the surface of the water, to which the main supporting surfaces and other parts are attached, and which contains accommodations for the crew.

LANDING GEAR.—The understructure of an aircraft designed to carry the load when in contact with the land or water.

SHOCK ABSORBER.—A spring or elastic member, designed to prevent the imposition of large accelerations on the fuselage, wings, and other heavy concentrated weights. Shock absorbers are usually interposed between the wheels, floats, or tail skid, and the remainder of the airplane to secure resiliency in landing and taxi-ing.

SHOCK-ABSORBER HYSTERESIS.—The ratio of the work absorbed in the shock absorber during one complete cycle to the total energy transmitted to the shock absorber during the first half of the cycle.

SKIDS.—Runners used as members of the landing gear and designed to aid the aircraft in landing or taxi-ing.

TAIL SKID.—A skid used to support the tail when in contact with the ground

WING SKID.—A skid placed near the wing tip and designed to protect the wing from contact with the ground.

Q. MISCELLANEOUS PARTS.

FINS.—Small stationary surfaces, substantially vertical, attached to different parts of aircraft, in order to promote stability; for example, tail fins, skid fins, etc. Fins are sometimes adjustable (Fig. 10.)

SKID FINS.—Fore-and-aft vertical surfaces, usually placed well out toward the tips of the upper plane, designed to provide the vertical keel surface required for stability.

STEP.—A break in the form of the bottom of a float or hull, designed to assist in securing a dynamic reaction from the water.

TAIL BOOM.—A spar or outrigger connecting the tail surfaces and main supporting surfaces. Usually used on pushers. (Fig. 3.)

TAIL PLANE.—A stationary horizontal, or nearly horizontal, tail surface, used to stabilize the pitching motion. Often called "stabilizer." (Fig. 10.)

TAIL UNIT.—The tail surfaces of an aircraft.

R. LANDING FIELDS, ETC.

AIRDROME.—A field providing facilities for aircraft to land and take-off, and equipped with hangars, shops, and a supply depot for the storage, maintenance, and repair of aircraft.

R. LANDING FIELDS, ETC.—Continued.

HANDLING TRUCK.—A truck, mounted on wheels or sliding on ways, on which airplanes or seaplanes may be placed to facilitate moving them about and carrying them to and from their hangars.

HANGAR.—A shelter for housing aircraft.

LANDING FIELD.—A field of such a nature as to permit of airplanes landing or takingoff.

S. OPERATION AND MANEUVERS.

AVIATOR.—The operator or pilot of heavier-than-air craft. This term is applied regardless of the sex of the operator.

BANK.—To incline an airplane laterally. Right bank is to incline the airplane with the right wing down. Also used as a noun to describe the position of an airplane when its lateral axis is inclined to the horizontal.

BARREL ROLL.—An aerial maneuver in which a complete revolution about the longitudinal axis is made, the direction of flight being approximately maintained.

DIVE.—A steep glide.

GLIDE, TO.—To descend at a normal angle of attack without engine power sufficient for level flight, the propeller thrust being replaced by a component of gravity along the line of flight.

LOOP.—An aerial maneuver in which the airplane describes an approximately circular path in the plane of the longitudinal and normal axes, the lateral axis remaining horizontal, and the upper side of the airplane remaining on the inside of the circle.

NOSE HEAVY.—The condition of an aircraft in which, in any given condition of normal flight, the nose tends to drop if the longitudinal control is released; i. e., the condition in which the pilot has to exert a pull on the control stick or column to maintain the given condition.

PANCAKE, TO.—To "level off" an airplane higher than for a normal landing, causing it to stall and descend with the wings at a very large angle of attack and approximately without bank, on a steeply inclined path.

REVERSE TURN.—A rapid maneuver to reverse the direction of flight of an airplane, made by a half loop and half roll in either sequence.

RIGGER.—One who is employed in assembling and aligning aircraft.

RIGGING.—The assembling and aligning of an aircraft.

SIDE SLIPPING.—Sliding with a component of velocity along the lateral axis which is inclined and in the direction of the lower end of that axis. When it occurs in connection with a turn it is the opposite of skidding (q. v.).

SKIDDING.—Sliding sidewise away from the center of curvature when turning. It is usually caused by banking insufficiently and is the opposite of side slipping (q. v.).

SOAR, TO.—To fly without engine power and without loss of altitude. Lightly loaded gliders will soar in rising currents of air.

SPIN.—An aerial maneuver consisting of a combination of roll and yaw, with the longitudinal axis of the airplane inclined steeply downward. The airplane descends in a helix of large pitch and very small radius, the upper side of the airplane being on the inside of the helix, and the angle of attack on the inner wing being maintained at an extremely large value.

STALLING.—A term describing the condition of an airplane which from any cause has lost the relative air speed necessary for control.

TAIL HEAVY.—The condition of an aircraft in which, in any given condition of normal flight, the nose tends to rise if the longitudinal control is released; i. e., the condition in which the pilot has to exert a push on the control stick or column to maintain the given condition.

S. OPERATION AND MANEUVERS—Continued.

TAIL SLIDE.—The rearward motion which certain airplanes may be made to take after having been brought into a stalling position.

TAXI, TO.—To run an airplane over the ground, or a seaplane on the surface of water, under its own power.

WARP, TO.—To change the form of a wing by twisting it. Warping is sometimes used to maintain the lateral equilibrium of an airplane.

ZOOM, TO.—To climb for a short time at an angle greater than that which can be maintained in steady flight, the machine being carried upward at the expense of its stored kinetic energy. This term is sometimes used by pilots to denote any sudden increase in the upward slope of the flight path.

T. DIMENSIONS AND CHARACTERISTICS.

ANGLE, GLIDING.—The acute angle which the flight path makes with the horizontal when descending in still air under the influence of gravity alone; i. e., without power from the engine.

ANGLE, LANDING.—The angle of attack of the main supporting surfaces of an airplane at the instant of touching the ground in a three-point landing; i. e., the angle between the wing chord and the horizontal when the machine is resting on the ground in its normal position.

ANGLE OF INCIDENCE (in directions for rigging).—In the process of rigging an airplane some arbitrary definite line in the airplane is kept horizontal; the angle of incidence of a wing, or of any aerofoil, is the angle between its chord and this horizontal line, which may be the line of the upper longerons of the fuselage or nacelle or the thrust line.

ANGLE OF TAIL SETTING.—The acute angle between the chord of the wings of an airplane and the chord of the tail plane. Denoted by the symbol $\beta$.

DIHEDRAL ANGLE.—The main supporting surfaces of an airplane are said to have a dihedral angle when both right and left wings are upwardly or downwardly inclined to a horizontal transverse line. The angle is measured by the inclination of each wing to the horizontal. If the inclination is upward, the angle is said to be positive; if downward, negative. The several main supporting surfaces of an airplane may have different amounts of dihedral. (Fig. 5.)

DOWNWASH ANGLE.—The acute angle through which the air stream relative to the airplane is deflected by an aerofoil. It is measured in a plane parallel to the plane of symmetry, and is denoted by the symbol $\epsilon$.

GAP.—The shortest distance between the planes of the chords of the upper and lower wings of a biplane, measured along a line perpendicular to the chord of the upper wing at any designated point of its entering edge. (Fig. 11.)

LENGTH OF FUSELAGE.—The distance from the nose of the fuselage (including the engine bed and radiator, if present) to the after end of the fuselage, not including the control and stabilizing surfaces.

MEAN CHORD OF A WING.—The quotient obtained by dividing the wing area by the extreme dimension of the wing projection at right angles to the chord.

MEAN CHORD OF A COMBINATION OF WINGS.—If $c$ be the mean chord of the combination; $c_1$, $c_2$, $c_3$, etc., the mean chords of each wing corresponding to areas $S_1$, $S_2$, $S_3$, etc., then

$$c=\frac{c_1S_1+c_2S_2+c_3S_3+\ \cdot\ \cdot\ \cdot\ \cdot}{S_1+S_2+S_3+\ \cdot\ \cdot\ \cdot\ \cdot}$$

T. DIMENSIONS AND CHARACTERISTICS—Continued.

MEAN SPAN OF A COMBINATION OF WINGS.—If $s$ be the mean span of the combination; $s_1$, $s_2$, and $s_3$, etc., the spans of each pair of wings separately corresponding to areas $S_1$, $S_2$, $S_3$, etc., then

$$s=\frac{s_1S_1+s_2S_2+s_3S_3+\ \cdot\ \cdot\ \cdot\ \cdot\ \cdot}{S_1+S_2+S_3+\ \cdot\ \cdot\ \cdot\ \cdot}$$

OVER-ALL LENGTH.—The distance from the extreme front to the extreme rear of an aircraft, including the propeller and the tail unit.

OVERHANG.—One-half the difference in the span of any two main supporting surfaces of an airplane. The overhang is positive when the upper of the two main supporting surfaces has the larger span. (Fig. 5.)

RAKE.—The cutting away of the wing tip at an angle so that the main supporting surfaces, seen from above, will appear of trapezoidal form. The amount of rake is measured by the angle between the straight portion of the wing-tip outline and the plane of symmetry. The rake is positive when the trailing edge is longer than the leading edge.

SPAN (or SPREAD).—The maximum distance laterally from tip to tip of an airplane inclusive of ailerons, or the lateral dimension of an aerofoil.

STAGGER.—The amount of advance of the entering edge of an upper wing of a biplane, triplane, or multiplane over that of a lower, expressed as percentage of gap; it is considered positive when the upper wing is forward, and is measured from the entering edge of the upper wing along its chord to the point of intersection of this chord with a line drawn perpendicular to the chord of the upper wing at the entering edge of the lower wing, all lines being drawn in a plane parallel to the plane of symmetry. (Fig. 11.)

In directions for rigging: The horizontal distance between the entering edge of the upper plane and that of the lower when the airplane is in the standard position; i. e., when the arbitrary line of reference in the airplane is horizontal. (This line is usually the axis of the propeller shaft.)

SWEEP BACK.—The angle, measured in a plane parallel to the lateral axis and to the chord of the main planes, between the lateral axis of an airplane and the entering edge of the main planes. (Fig. 16.)

WASH.—The disturbance in the air produced by the passage of an aerofoil.

WASHIN.—A permanent increase in the angle of attack near the tip of the wing.

WASHOUT.—A permanent decrease in the angle of attack near the tip of the wing.

WING LOADING.—The weight carried per unit area of supporting surface. The area used in computing the wing loading should include the ailerons, but not the tail-plane or elevators.

U. STABILITY THEORY.

DAMPING FACTOR.—The percentage of damping in one period; i. e., $1-e^{-\lambda T}$, where $\lambda T$ is the logarithmic decrement (q. v.).

DIVERGENCE.—A disturbance which increases without oscillation.

LOGARITHMIC DECREMENT.—The natural logarithm of the ratio of two successive amplitudes of an oscillation; i. e., at an interval of one period. The general equation of an oscillation may be written

$$s=Ae^{-\lambda t}\sin(pt-\alpha),$$

in which $A$, $\lambda$, $p$, and $\alpha$ are constants. The amplitude of oscillation is $Ae^{-\lambda t}$. The phase of the vibration is $pt-\alpha$. The period is $2\pi/p$, and may be written $T$.

It follows that the logarithmic decrement is $\lambda T$. If $\lambda$ is a positive number, the vibration is said to be "damped." (In an unstable oscillation (q. v.), the quantity $\lambda$ is a negative number.)

PERIOD.—The time taken for a complete oscillation.

U. STABILITY THEORY—Continued.

PHUGOID OSCILLATION.—A long period oscillation characteristic of the disturbed longitudinal motion of an airplane.

RESISTANCE DERIVATIVES.—Quantities expressing the variation of the forces and moments on aircraft due to disturbance of steady motion. They form the experimental basis of the theory of stability, and from them the periods and damping factors of aircraft can be calculated. In the general case there are 18 translatory and 18 rotary derivatives.

ROTARY.—Resistance derivatives expressing the variation of moments and forces due to small increases in the rotational velocities of the aircraft.

TRANSLATORY.—Resistance derivatives expressing the variation of moments and forces due to small increases in the translatory velocities of the aircraft.

RIGHTING MOMENT.—A moment which tends to restore an aircraft to its previous attitude after any small rotational displacement.

SPIRAL INSTABILITY.—The instability on account of which an airplane tends to depart from straight flight, by a combination of side slipping and banking, the latter being always too great for the turn.

STABILITY:

(*a*) STATIC STABILITY.—A machine is statically stable if, when slightly displaced by rotation about its center of gravity (as in wind tunnel experimentations), moments come into play which tend to return the machine to its normal attitude.

(*b*) DYNAMICAL STABILITY.—A machine is dynamically stable if, when displaced from steady motion in flight, it tends to return to that steady state of motion.

In a general way, the difference between static stability and dynamical stability is that the former depends on restoring moments and the latter on damping factors.

AUTOMATIC.—Stability dependent upon movable control surfaces. The term "automatic stability" is usually applied to those cases in which the control surfaces are automatically operated by mechanical means.

DIRECTIONAL.—Stability with reference to rotations about the normal axis; i. e., a machine possessing directional stability in its simplest form is one for which $Nv$ is negative. Owing to symmetry, directional stability is closely associated with lateral stability.

INHERENT.—Stability of an aircraft due solely to the disposition and arrangement of its fixed parts; i. e., that property which causes it when disturbed to return to its normal attitude of flight without the use of the controls or the interposition of any mechanical device.

LATERAL.—Stability with reference to disturbances involving rolling, yawing, or side slipping; i. e., disturbances in which the position of the plane of symmetry of the aircraft is affected.

LONGITUDINAL.—Stability with reference to disturbances in the plane of symmetry; i. e., disturbances involving pitching and variations of the longitudinal and normal velocities.

STABLE OSCILLATION.—An oscillation which tends to die out.

UNSTABLE OSCILLATION.—An oscillation of which the amplitude tends to increase.

## ENGINE TERMS.

V. ENGINE TERMS.

CONSUMPTION PER B. H. P. HOUR.—The quantity of fuel or oil consumed per hour by an engine running at ground level divided by the brake-horsepower developed, unless specifically stated otherwise.

DRY WEIGHT.—The weight of an engine including carburetors, propeller hub assembly, and ignition system complete, but excluding exhaust manifolds, oil, and water.

V. ENGINE TERMS—Continued.

HORSEPOWER OF AN ENGINE, MAXIMUM.—The maximum horsepower which can be safely maintained for periods not less than five minutes.

HORSEPOWER OF AN ENGINE, NORMAL.—The highest horsepower which can be safely maintained for long periods.

REVOLUTIONS, MAXIMUM.—The maximum number of revolutions per minute that may be maintained for periods not less than five minutes.

REVOLUTIONS, NORMAL.—The highest number of revolutions per minute that may be maintained for long periods.

RIGHT-HAND ENGINE.—An engine the final power delivery shaft of which rotates clockwise when viewed by an observer looking along the engine toward the power delivery end.

WEIGHT PER HORSEPOWER.—The dry weight of an engine divided by the normal horsepower developed at ground level.

# REPORT No. 91

## NOMENCLATURE FOR AERONAUTICS

By the National Advisory Committee for Aeronautics

### PART II.

### ALPHABETICAL NOMENCLATURE

AERODYNAMIC PITCH.—(*See* Pitch.)

AEROFOIL.—A winglike structure, flat or curved, designed to obtain reaction upon its surfaces from the air through which it moves.

AEROFOIL SECTION.—A section of an aerofoil made by a plane parallel to the plane of symmetry of the aerofoil and to the normal direction of motion.

AERONAUT.—The pilot of an aerostat.

AEROSTAT.—An aircraft which embodies a container filled with a gas lighter than air and which is sustained by the buoyancy of this gas; e. g., airship, balloon.

AEROSTATICS.—The science which relates to the buoyancy and behavior of lighter-than-air craft.

AEROSTATION.—The operation of balloons and airships. Corresponds to aviation (q. v.). but refers to lighter-than-air craft.

AILERON.—A hinged or pivoted movable auxiliary surface of an airplane, usually part of the trailing edge of a wing, the primary function of which is to impress a rolling moment on the airplane. (Fig. 1.)

AIR SCOOP.—A projecting cowl, which, by using the dynamic pressure of the relative wind or slip-stream, serves to maintain air pressure in the interior of the ballonet of an aerostat. (Fig. 2.)

AIRCRAFT.—Any form of craft designed for the navigation of the air—airplanes, airships, balloons, helicopters, kites, kite balloons, ornithopters, gliders, etc.

AIRDROME.—A field providing facilities for aircraft to land and take off and equipped with hangars, shops, and a supply depot for the storage, maintenance, and repair of aircraft.

AIRPLANE.—A form of aircraft heavier than air which obtains support by the dynamic reaction of the air against the wings and which is driven through the air by a screw propeller, This term is commonly used in a more restricted sense to refer to airplanes fitted with landing gear suited to operation from the land. If the landing gear is suited to operation from the water, the term "seaplane" is used. (See definition.)

- Pusher.—A term commonly applied to a single-engine airplane with the propeller in the rear of the main supporting surfaces. (Fig. 3.)
- Tandem.—An airplane with two or more sets of wings of substantially the same area (not including the tail unit) placed one in front of the other and on about the same level.
- Tractor.—A term commonly applied to a single-engined airplane with the propeller forward of the main supporting surfaces. (Fig. 4.)

AIRSHIP.—A form of aerostat provided with a propelling system and with means of controlling the direction of movement.

- Nonrigid.—An airship whose form is maintained by the pressure of the contained gas.
- Rigid.—An airship whose form is maintained by a rigid structure contained within the the envelope.
- Semirigid.—An airship whose form is maintained by means of a rigid or jointed keel and by gas pressure.

AIR SPEED.—(*See* Speed.)

AIR-SPEED INDICATOR.—(*See* Indicator.)

ALTIMETER.—An aneroid barometer, mounted on an aircraft, whose dial is marked in feet, yards, or meters.

ANEMOMETER.—Any instrument for measuring the velocity or force of the wind.

ANGLE, CRITICAL.—The angle of attack at which the flow about an aerofoil changes abruptly, with corresponding abrupt changes in the lift and drag coefficients. An aerofoil may have two or more critical angles, one of which almost always corresponds to the angle of maximum lift.

ANGLE, DIHEDRAL.—The main supporting surfaces of an airplane are said to have a dihedral angle when both right and left wings are upwardly or downwardly inclined to a horizontal transverse line. The angle is measured by the inclination of each wing to the horizontal. If the inclination is upward, the angle is said to be positive; if downward, negative. The several main supporting surfaces of an airplane may have different amounts of dihedral. (Fig. 5.)

ANGLE, DOWNWASH.—The acute angle through which the air stream relative to the airplane is deflected by an aerofoil. It is measured in a plane parallel to the plane of symmetry, and is denoted by the symbol $\epsilon$.

ANGLE, GLIDING.—The acute angle which the flight path makes with the horizontal when descending in still air under the influence of gravity alone; i. e., without power from the engine.

ANGLE, LANDING.—The angle of attack of the main supporting surfaces of an airplane at the instant of touching the ground in a three-point landing; i. e., the angle between the wing chord and the horizontal when the machine is resting on the ground in its normal position.

ANGLE OF ATTACK.—The acute angle between the direction of the relative wind and the chord of an aerofoil; i. e., the angle between the chord of an aerofoil and its motion relative to the air. (This definition may be extended to any body having an axis.)

ANGLE OF INCIDENCE (in directions for rigging).—In the process of rigging an airplane some arbitrary definite line in the airplane is kept horizontal; the angle of incidence of a wing, or of any aerofoil, is the angle between its chord and this horizontal line, which may be the line of the upper longerons of the fuselage or nacelle or the thrust line.

ANGLE OF PITCH.—The angle between two planes defined as follows: One plane includes the lateral axis of the aircraft and the direction of the relative wind; the other plane includes the lateral axis and the longitudinal axis. (In normal flight the angle of pitch is, then, the angle between the longitudinal axis and the direction of the relative wind.) This angle is denoted by $\theta$, and is positive when the nose of the aircraft rises.

ANGLE OF PROPELLER BLADE SETTING.—The angle which the chord of a propeller section makes with a plane perpendicular to the axis of the propeller. This angle varies along the blade, increasing as the boss is approached.

ANGLE OF ROLL, or ANGLE OF BANK.—The angle through which an aircraft must be rotated about its longitudinal axis in order to bring its lateral axis into a horizontal plane. This angle is denoted by $\phi$.

ANGLE OF TAIL SETTING.—The acute angle between the chord of the wings of an airplane and the chord of the tail plane. Denoted by the symbol $\beta$.

ANGLE OF YAW.—The angle between the direction of the relative wind and the plane of symmetry of an aircraft. This angle is denoted by $\psi$, and is positive when the aircraft turns to the right.

ANGLE OF ZERO LIFT.—(*See* Zero lift angle.)

ANTIDRAG WIRES.—(*See* Wires.)

ANTILIFT WIRES.—(*See* Wires.)

APPARENT PRESSURE.—The excess of pressure inside the envelope of an aerostat over the atmospheric pressure. In the case of an airship, the excess of pressure is measured at the bottom of the envelope unless otherwise specified.

APPENDIX.—The tube at the bottom of a balloon, used for inflation. In the case of a spherical balloon it also serves to increase the "head" of gas, and so to build up an internal pressure sufficient to keep the envelope from being pulled out of shape by the weight of the basket. (Fig. 6.)

ASPECT RATIO.—The ratio of span to mean chord of an aerofoil.

ASPECT RATIO OF PROPELLERS.—The ratio of propeller diameter to maximum blade width.

ATTACK, ANGLE OF.—(*See* Angle.)

ATTITUDE.—The attitude of an aircraft is determined by the inclination of its axes to a "frame of reference" fixed to the earth; i. e., the attitude depends entirely on the position of the aircraft as seen by an observer on the ground.

AUTOMATIC VALVE.—An automatic escape and safety valve for the purpose of regulating internal pressure in an aerostat.

AVIATOR.—The operator or pilot of heavier-than-air craft. This term is applied regardless of the sex of the operator.

AXES OF AN AIRCRAFT.—Three fixed lines of reference; usually centroidal and mutually rectangular. (Fig. 7.)

The principal longitudinal axis in the plane of symmetry, usually parallel to the axis of the propeller, is called the longitudinal axis; the axis perpendicular to this in the plane of symmetry is called the normal axis; and the third axis, perpendicular to the other two, is called the lateral axis. In mathematical discussions the first of these axes, drawn from front to rear, is called the $X$ axis; the second, drawn upward, the $Z$ axis; and the third, running from right to left, the $Y$ axis.

BALANCED SURFACE.—(*See* Surface.)

BALLONET.—A small balloon within the interior of a balloon or airship for the purpose of controlling the ascent or descent and for maintaining pressure on the outer envelope so as to prevent deformation.

BALLOON.—A form of aerostat deriving its support in the air from the buoyancy of the air displaced by an envelope the form of which is maintained by the pressure of a contained gas lighter than air, and having no power plant or means of controlling the direction of flight in the horizontal plane.

BARRAGE.—A small captive balloon, raised as a protection against attacks by airplanes.

CAPTIVE.—A balloon restrained from free flight by means of a cable attaching it to the earth.

KITE.—An elongated form of captive balloon, fitted with tail appendages to keep it headed into the wind, and usually deriving increased lift due to its axis being inclined to the wind. A Caquot balloon is of this type. (Fig. 8.)

NURSE.—A small balloon made of heavy fabric, employed as a portable means for storing gas. Sometimes one is so connected as to automatically allow for the expansion or contraction of the gas in an aerostat when on the ground.

PILOT.—A small balloon sent up to show the direction of the wind by observations of its flight with theodolites.

SOUNDING.—A small balloon sent aloft without passengers but with registering meteorological and other instruments.

BALLOON BED.—A mooring place on the ground for a captive balloon.

BALLOON FABRIC.—(*See* Fabric.)

BANK.—To incline an airplane laterally. Right bank is to incline the airplane with the right wing down. Also used as a noun to describe the position of an airplane when its lateral axis is inclined to the horizontal.

BANK, ANGLE OF.—(*See* Angle of roll.)

BAROGRAPH.—An instrument used to make a permanent record of variations in barometric pressure. In aeronautics the charts on which the records are made sometimes indicate altitudes directly instead of barometric pressures.

BARRAGE BALLOON.—(*See* Balloon.)

BARREL ROLL.—An aerial maneuver in which a complete revolution about the longitudinal axis is made, the direction of flight being approximately maintained.

BASKET.—The car suspended beneath a balloon, for passengers, ballast, etc.

BAY.—The cubic section of a truss included between two transversely adjacent sets of struts of an airplane. The first bay is the one closest to the plane of symmetry.

BIPLANE.—A form of airplane whose main supporting surface is divided into two parts, superimposed.

BLADE BACK.—The markedly convex surface of a propeller blade which corresponds to the upper surface of an aerofoil.

BLADE FACE.—The surface of a propeller blade, flat or slightly cambered near the tips, which corresponds to the lower surface of an aerofoil.

BLADE SETTING, ANGLE OF.—(*See* Angle.)

BLADE WIDTH RATIO.—The ratio of the width of a propeller blade at any point to the circumference of the circle along which that point travels when the propeller is rotating and the airplane is held stationary. When used without qualifying terms, it refers to the ratio of the maximum blade width to the circumference of the circle swept by the propeller.

BOAT SEAPLANE.—(*See* Seaplane.)

BONNET.—The appliance, having the form of a parasol, which protects the valve of a spherical balloon against rain.

BOSS.—The central portion of an airscrew. The portion in which the hub is mounted.

BOW STIFFENERS.—Rigid members attached to the bow of a nonrigid or semirigid envelope to reinforce it against the pressure caused by the motion of the airship. (Sometimes called nose stiffeners.)

BRIDLE.—A sling of cordage which has its ends attached to the envelope of a balloon or airship and a rope or cable running from an intermediate point.

BULKHEAD.—A transverse structural member of a fuselage or nacelle, continuous around the periphery.

BUOYANCY.—The upward force exerted on a lighter-than-air craft due to the air which it displaces.

- CENTER OF.—The center of volume of the gas container or the center of gravity of the gas (envelope) of a balloon or airship.
- GROSS.—The total upward force on an aerostat at rest: the total volume multiplied by the difference of density of the air and the contained gas.
- POSITIVE AND NEGATIVE.—The positive or negative difference between the buoyancy and the weight of a balloon or airship. The unbalanced force which causes ascent or descent.

CABANE.—A pyramidal or prismoidal framework to which wire or cable stays are secured.

CAMBER.—The convexity or rise of the curve of an aerofoil from its chord, usually expressed as the ratio of the maximum departure of the curve from the chord to the length of the chord. "Top camber" refers to the top surface of an aerofoil and "bottom camber" to the bottom surface; "mean camber" is the mean of these two.

CAMBER RATIO.—The ratio of the maximum ordinate of a propeller section to its chord.

CAPACITY.—The cubic contents or volume of an aerostat.

CAPTIVE BALLOON.—(*See* Balloon.)

CAQUOT BALLOON.—(*See* Balloon, kite.)

CAR.—The nacelle of an airship.

CEILING:

- ABSOLUTE.—The maximum height above sea level which a given aircraft can approach asymptotically, assuming standard air conditions.
- SERVICE.—The height above sea level at which a given aircraft ceases to rise at a rate higher than a small specified one (100 feet per minute in United States Air Service). This specified rate may be different in the services of different countries.

CELL.—The entire structure of the wings and wing trussing on one side of the fuselage of an airplane, or between fuselages or nacelles, where there are more than one.

CENTER OF PRESSURE OF AN AEROFOIL SECTION.—The point in the chord of an aerofoil section, prolonged if necessary, through which at any given attitude the line of action of the resultant air force passes.

CHORD:

OF AN AEROFOIL SECTION.—The line of a straightedge brought into contact with the lower surface of the section at two points. In the case of an aerofoil having double convex camber the straight line joining the leading and trailing edges. (These edges may be defined, for this purpose, as the two points in the section which are farthest apart.) (Fig. 9.)

LENGTH.—The length of the projection of the aerofoil section on its chord.

CHORD, MEAN, OF A WING.—The quotient obtained by dividing the wing area by the extreme dimension of the wing projection at right angles to the chord.

CHORD, MEAN, OF A COMBINATION OF WINGS.—If $c$ be the mean chord of the combination $c_1$, $c_2$, $c_3$, etc., the mean chords of each wing corresponding to areas $S_1$, $S_2$, $S_3$, etc., then

$$c=\frac{c_1 S_1+c_2 S_2+c_3 S_3+ \quad . \quad . \quad . \quad .}{S_1+S_2+S_3+ \quad . \quad . \quad . \quad .}$$

CLIMB, RATE OF.—The vertical component of the air speed of an aircraft; i. e., its vertical velocity with reference to the air.

COCKPIT.—The open spaces in which the pilot and passengers are accommodated. A cockpit is never completely housed in.

CONCENTRATION RING:

AIRSHIP.—A metal ring to which several rigging lines are brought from the envelope and from which one or more lines also lead to the car.

FREE BALLOON.—A hoop to which are attached the ropes suspending the basket and to which the net is also secured.

PARACHUTE.—A hoop to which the rigging of the parachute is attached and also the line sustaining the passenger.

CONSUMPTION PER B. H. P. HOUR.—The quantity of fuel or oil consumed per hour by an engine running at ground level divided by the brake horsepower developed, unless specifically stated otherwise.

CONTROL COLUMN OR YOKE.—A control lever with a rotatable wheel mounted at its upper end. (*See* Control stick.) Pitching is controlled by fore-and-aft movement of the column; rolling, by rotation of the wheel. "Wheel control" is that type of control in which such a column or yoke is used.

CONTROL STICK.—The vertical lever by means of which certain of the principal controls of an airplane are operated. Pitching is controlled by a fore-and-aft movement of the stick, rolling by a side-to-side movement. "Stick control" is that type of control in which such a stick is used.

CONTROLS.—A general term applying to the means provided to enable the pilot to control the speed, direction of flight, attitude, and power of an aircraft.

CORD.—A species of wire made up of several strands (usually 7) twisted together as in a rope, each of the strands, in turn, being made up of several (usually 19) individual wires.

COWLING.—The metal covering which houses the engine and sometimes a portion of the fuselage or nacelle as well.

CRITICAL ANGLE.—(*See* Angle.)

CROSS-WIND FORCE.—The component perpendicular to the lift and to the drag of the total force on an aircraft due to the air through which it moves.

CROW'S-FOOT.—A system of diverging short ropes for distributing the pull of a single rope.

DAMPING FACTOR.—The percentage of damping in one period, i. e., $1=e-\lambda T$, where $\lambda T$ is the logarithmic decrement (q. v.).

DEAD LOAD.—(*See* Load.)

DIHEDRAL ANGLE.—(*See* Angle.)

DISK AREA.—The total area swept by a propeller, i. e., the area of a circle having a diameter equal to the propeller diameter.

DISCHARGEABLE WEIGHT.—The excess of the gross buoyancy over the dead load, the crew and such items of equipment as are essential to enable an airship to fly and land safely.

DIVE.—A steep glide.

DIVERGENCE.—A disturbance which increases without oscillation.

DOPE, AIRPLANE.—A general term applied to the material used in treating the cloth surface of airplane members to increase strength, produce tautness, and act as a filler to maintain air-tightness.

DOWNWASH ANGLE.—(*See* Angle.)

DRAG.—The component parallel to the relative wind of the total force on an aerofoil or aircraft due to the air through which it moves.

In the case of an airplane, that part of the drag due to the wings is called "wing resistance;" that due to the rest of the airplane is called "structural," or "parasite resistance."

DRAG ROPE.—The rope dropped by an airship in order to allow it to be secured by a landing party.

DRAG STRUT.—A compression member of the internal bracing system of an aerofoil.

DRAG WIRES.—(*See* Wires.)

DRIFT.—The angular deviation from a set course over the earth, due to cross currents of wind; hence, "drift meter."

DRIFT METER.—An instrument for the measurement of the angular deviation of an aircraft from a set course, due to cross winds.

DRIP FLAP.—A strip of fabric attached by one edge to the envelope of an aerostat so that rain runs off its free edge instead of dripping into the basket or car. The drip flap assists also to keep the suspension ropes dry and nonconducting.

DRY WEIGHT.—The weight of an engine, including carburetors, propeller-hub assembly, and ignition system, complete, but excluding exhaust manifolds.

DYNAMIC FACTOR.—The ratio between the load carried by any part of an aircraft when accelerating or when otherwise subjected to abnormal conditions and the load carried in normal flight.

DYNAMIC LIFT.—(*See* Lift.)

EFFECTIVE PITCH.—(*See* Pitch.)

ELEVATOR.—A movable auxiliary surface of an airplane, usually attached to the tail plane, the function of which is to impress a pitching moment on the aircraft. (Fig. 10.)

EMPENNAGE.—Same as Tail unit (q. v.).

ENVELOPE.—The outer covering of a rigid airship; or, in the case of a balloon or a nonrigid airship, the bag which contains the gas.

EQUATOR.—The largest horizontal circle of a spherical balloon.

FABRIC, BALLOON.—The finished material, usually rubberized, of which balloon or airship envelopes are made.

BIASED.—Plied fabric in which the threads of the plies are at an angle to each other.

PARALLEL.—Plied fabric in which the threads of the plies are parallel to each other.

FACTOR, DYNAMIC.—(*See* Dynamic factor.)

FACTOR OF SAFETY.—The ratio of the ultimate strength of a member to the maximum possible load occurring under conditions specified.

FAIRING.—A member whose primary function is to produce a smooth outline and to reduce head resistance or drag.

FINS.—Small stationary surfaces, substantially vertical, attached to different parts of aircraft, in order to promote stability; for example, tail fins, skid fins, etc. Fins are sometimes adjustable. (Fig. 10.)

SKID FINS.—Fore and aft vertical surfaces, usually placed well out toward the tips of the upper plane, designed to provide the vertical keel-surface required for stability.

FINS, KITE BALLOON.—The air-inflated lobes intended to keep the balloon headed into the wind.

FIRE WALL.—A metal plate, so set as to isolate from the engine the other parts of the airplane structure, and thus to reduce the risk from a backfire.

FITTING.—A generic term for any small metal part used in the structure of an airplane.

FLIGHT PATH.—The path of the center of gravity of an aircraft with reference to the earth.

FLOAT.—A completely inclosed water-tight structure attached to an aircraft in order to furnish it buoyancy when in contact with the surface of the water. In float seaplanes the crew is carried in a fuselage or nacelle separate from the float.

FLOAT SEAPLANE.—(*See* Seaplane.)

FLOTATION GEAR.—An emergency landing gear attached to an airplane, which will permit of safe landing on the water and provide buoyancy when resting on the surface of the water.

FLYING BOAT.—(*See* Seaplane.)

FREE-FLIGHT TESTING.—The conduct of special flight tests of a scientific nature, as contrasted with performance testing (q. v.).

FULL LOAD.—(*See* Load.)

FUSELAGE.—The elongated structure, of approximately streamline form, to which are attached the wings and tail unit of an airplane. In general it is designed to hold the passengers.

FUSELAGE, LENGTH OF.—The distance from the nose of the fuselage (including the engine bed and radiator, if present) to the after end of the fuselage, not including the control and stabilizing surfaces.

GAP.—The shortest distance between the planes of the chords of the upper and lower wings of a biplane, measured along a line perpendicular to the chord of the upper wing at any designated point of its entering edge. (Fig. 11.)

GEOMETRICAL PITCH.—(*See* Pitch.)

GLIDE, TO.—To descend at a normal angle of attack without engine power sufficient for level flight, the propeller thrust being replaced by a component of gravity along the line of flight.

GLIDER.—A form of aircraft similar to an airplane, but without any power plant. Gliders are used chiefly for sport.

GLIDING ANGLE.—(*See* Angle.)

GORE.—The portion of the envelope of a balloon or airship included between two adjacent meridian seams.

GROSS BUOYANCY.—(*See* Buoyancy.)

GROUND CLOTH.—Canvas placed on the ground to protect a balloon.

GROUND SPEED.—(*See* Speed.)

HANDLING TRUCK.—A truck, mounted on wheels or sliding on ways, on which airplanes or seaplanes may be placed to facilitate moving them about and carrying them to and from their hangars.

HANGAR.—A shelter for housing aircraft.

HELICOPTER.—A form of aircraft whose support in the air is derived from the vertical thrust of propellers.

HOG (AIRSHIP).—A distortion of the envelope in which the axis becomes convex upward or both ends droop.

HORN.—The operating lever of a control surface of an aircraft, e. g., aileron horn, rudder horn, elevator horn.

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HORSEPOWER OF AN ENGINE, MAXIMUM.—The maximum horsepower which can be safely maintained for periods not less than five minutes.

HORSEPOWER OF AN ENGINE, NORMAL.—The highest horsepower which can be safely maintained for long periods.

HULL (AIRSHIP).—The main structure of a rigid airship, consisting of a covered elongated framework which incloses the gas bags and which supports the cars and equipment.

HULL (SEAPLANE).—The portion of a boat seaplane which furnishes buoyancy when in contact with the surface of the water, to which the main supporting surfaces and other parts are attached, and which contains accommodations for the crew.

INCIDENCE, ANGLE OF.—(*See* Angle.)

INCLINOMETER:

ABSOLUTE.—An instrument giving the attitude of an aircraft with reference to true gravity.

RELATIVE.—An instrument giving the attitude of an aircraft with reference to apparent gravity. Such instruments are sometimes incorrectly referred to as banking indicators

INDICATOR, AIR-SPEED.—An anemometer mounted on an aircraft for the purpose of indicating the speed of the aircraft.

TRUE AIR-SPEED INDICATOR.—An instrument, usually working on the principle of the Biram or Robinson anemometers, which gives the true air speed, independent of density.

APPARENT AIR-SPEED INDICATOR.—An instrument, usually dependent on pressure measurements, the readings of which vary with the density of the air.

INDRAFT.—The drawing in of air from in front of a propeller by the action of the rotating blades. The indraft velocity relative to the propeller is somewhat higher than that of the undisturbed air at most points of the propeller disk.

INSPECTION WINDOW.—A small transparent window in the envelope of a balloon or in the wing of an airplane to allow inspection of the interior.

JACKSTAY.—A longitudinal rigging provided to maintain the correct distance between the heads of various riggings on an airship.

KEEL.—A member or assembly of members which provides longitidunal strength to an airship of rigid or semirigid type. In the case of a rigid airship the keel is usually an elaborately trussed girder and may be inclosed within the envelope or may project beyond (usually below) the regular cross-sectional form of the envelope.

ARTICULATED.—A keel made up of a series of members hinged together at their ends.

KING POST.—The main compression member of a trussing system applied to a member subject to bending. (Fig. 4.)

KITE.—A form of aircraft without other propelling means then the towline pull, whose support is derived from the force of the wind moving past its surface.

KITE BALLOON.—(*See* Balloon.)

LAMINATED WOOD.—Wooden parts made up by gluing or otherwise fastening together individual wood planks or laminations with the grain substantially parallel.

LANDING ANGLE.—(*See* Angle.)

LANDING FIELD.—A field of such a nature as to permit of airplanes landing or taking off.

LANDING GEAR.—The understructure of an aircraft designed to carry the load when in contact with the land or water.

LEADING EDGE.—The foremost edge of an aerofoil or propeller blade.

LENGTH, CHORD.—(*See* Chord.)

LENGTH, FUSELAGE.—(*See* Fuselage.)

LENGTH, OVER-ALL.—(*See* Over-all.)

LIFT.—The component of the total air force which is perpendicular to the relative wind and in the plane of symmetry. It must be specified whether this applies to a complete aircraft or parts thereof. (In the case of an airship this is often called "dynamic lift.")

LIFT WIRES.—(*See* Wires.)

LOAD:

DEAD.—The structure, power plant, and essential accessories of an aircraft. Included in this are the water in the radiator, tachometer, thermometer, gauges, air-speed indicators, levels, altimeter, compass, watch and hand starter, and also, in the case of an aerostat, the amount of ballast which must be carried to assist in making a safe landing.

FULL.—The total weight of an aircraft when loaded to the maximum authorized loading of that particular type.

USEFUL.—The excess of the full load over the dead load of the aircraft itself. Therefore useful load includes the crew and passengers, oil and fuel, ballast, electric-light installation, chart board, detachable gun mounts, bomb storage and releasing gear, wireless apparatus, etc.

LOAD FACTOR.—The ratio of the ultimate strength of a member to the load under horizontal steady rectilinear flight conditions.

LOBES.—Inflated bags at the stern of an elongated balloon, designed to give it directional stability. Also used to denote the sections into which the envelope is sometimes (e. g., in the Astra-Torres) divided by the tension of the internal rigging.

LOGARITHMIC DECREMENT.—The natural logarithm of the ratio of two successive amplitudes of an oscillation; i. e., at an interval of one period. The general equation of an oscillation may be written

$$s = Ae^{-\lambda t} \sin (pt - \alpha),$$

in which $A$, $\lambda$, $p$, and $\alpha$ are constants. The amplitude of oscillation is $Ae^{-\lambda t}$. The phase of the vibration is $pt - \alpha$. The period is $2\pi/p$, and may be written $T$. It follows that the logarithmic decrement is $\lambda T$. If $\lambda$ is a positive number, the vibration is said to be "damped." [In an unstable oscillation (q. v.), the quantity $\lambda$ is a negative number.]

LONGERON.—A fore-and-aft member of the framing of an airplane fuselage or nacelle, usually continuous across a number of points of support. (Fig. 12.)

LOOP.—An aerial maneuver in which the airplane describes an approximately circular path in the plane of the longitudinal and normal axes, the lateral axis remaining horizontal, and the upper side of the airplane remaining on the inside of the circle.

MAIN SUPPORTING SURFACE.—(*See* Surface.)

MARGIN OF POWER.—(*See* Power.)

MEAN CHORD OF A WING.—(*See* Chord.)

MEAN CHORD OF A COMBINATION OF WINGS.—(*See* Chord.)

MEAN SPAN.—(*See* Span, mean.)

MINIMUM SPEED.—(*See* Speed.)

MONOCOQUE.—A type of fuselage which is constructed by wrapping strips of veneer around formers, and in which the veneer is primarily depended on to carry stresses arising in the fuselage.

MONOPLANE.—A form of airplane which has but one main supporting surface extending equally on each side of the body.

MOORING HARNESS.—The system of bands of tape over the top of a balloon to which are attached the mooring ropes.

MULTIPLANE.—A form of airplane whose main supporting surface is divided into four parts, superimposed.

NACELLE.—The inclosed shelter for passengers or for a power plant. A nacelle is usually shorter than a fuselage, and does not carry the tail unit.

NET.—A rigging made of ropes and twine on spherical balloons which supports the weight of the basket, etc., distributing the load over the entire upper surface of the envelope.

NONRIGID AIRSHIP.—(*See* Airship.)

NOSE CAP.—A cap used to reinforce the bow stiffeners of an airship.

NOSE HEAVY.—The condition of an aircraft in which, in any given condition of normal flight, the nose tends to drop if the longitudinal control is released; i. e., the condition in which the pilot has to exert a pull on the control stick or column to maintain the given condition.

NURSE BALLOON.—(*See* Balloon.)

ORNITHOPTER.—A form of aircraft deriving its support and propelling force from flapping wings.

OSCILLATION, PHUGOID.—A long period oscillation characteristic of the disturbed longitudinal motion of an airplane.

OSCILLATION, STABLE.—An oscillation which tends to die out.

OSCILLATION, UNSTABLE.—An oscillation of which the amplitude tends to increase.

OVER-ALL LENGTH.—The distance from the extreme front to the extreme rear of an aircraft, including the propeller and the tail unit.

OVERHANG.—One-half the difference in the span of any two main supporting surfaces of an airplane. The overhang is positive when the upper of the two main supporting surfaces has the larger span. (Fig. 5.)

PANCAKE, TO.—To "level off" an airplane higher than for a normal landing, causing it to stall and descend with the wings at a very large angle of attack and approximately without bank, on a steeply inclined path.

PANEL AEROSTAT.—The unit piece of fabric of which the envelope of an aerostat is made.

PANEL AIRPLANE.—A portion of a wing of an airplane which is constructed entirely separately from the rest of the wing, and which is attached to the remainder by bolts and fittings.

PARACHUTE.—An apparatus used to retard the descent of a falling body by offering resistance to motion through the air; usually made of light fabric with no rigid parts.

PARASITE RESISTANCE.—(*See* Drag.)

PATCH, AIRSHIP.—A strengthened or reinforced flap of fabric, of variable form according to the maker, which is cemented to the envelope and forms an anchor by which some portion of the machine is attached to the envelope. (Fig. 2.)

PERFORMANCE.—The maximum and minimum speeds and rate of climb at various altitudes, the time to climb to these altitudes, and the ceiling constitute the performance characteristics of an airplane.

PERFORMANCE TESTING.—The process of determining the performance characteristics of an airplane.

PERIOD.—The time taken for a complete oscillation.

PERMEABILITY.—The measure of the rate of diffusion of gas through intact balloon fabric; usually expressed in cubic meters per square meter per 24 hours.

PHILLIPS' ENTRY.—A reversal of curvature of the lower surface of an aerofoil near the leading edge. The result is to decrease the drag and provide more depth for the front spar. (Fig. 9.)

PHUGOID OSCILLATION.—(*See* Oscillation.)

PILOT BALLOON.—(*See* Balloon.)

PITCH OF A PROPELLER:

PITCH, AERODYNAMIC.—The distance a propeller would have to advance in one revolution in order that the torque might be zero.

PITCH, EFFECTIVE.—The distance an aircraft advances along its flight path for one revolution of the propeller.

PITCH, GEOMETRICAL.—The distance an element of a propeller would advance in one revolution if it were turning in a solid nut; i. e., if it were moving along a helix of slope equal to the angle between the chord of the element and a plane perpendicular to the propeller axis. The mean geometrical pitch of a propeller, which is a quantity commonly used in specifications, is the mean of the geometrical pitches of the several elements.

PITCH OF A PROPELLER—Continued.

PITCH, STANDARD.—The "pitch of a propeller" is usually stated as the geometrical pitch taken at two-thirds of the radius.

PITCH, VIRTUAL.—The distance a propeller would have to advance in one revolution in order that there might be no thrust.

PITCH, ANGLE OF.—(*See* Angle.)

PITCH SLIP.—(*See* Slip.)

PITCH SPEED.—(*See* Speed.)

PITOT TUBE.—A tube with an end open square to a fluid stream. It is exposed with the open end pointing upstream to detect an impact pressure. It is usually associated with a coaxial tube surrounding it, having perforations normal to the axis for indicating static pressure; or there is such a tube placed near it and parallel to it, with a closed conical end and having perforations in its side. The velocity of the fluid can be determined from the difference between the impact pressure and the static pressure, as read by a suitable gauge. This instrument is often used to determine the velocity of an aircraft through the air. (Fig. 13.)

PLYWOOD.—A product formed by gluing together two or more layers of wood veneer.

POWER, MARGIN OF.—The difference between the power available at any given speed and in air of given density and the power required for level flight under the same conditions. The best rate of climb at any altitude depends on the maximum margin of power.

POWER LOADING.—The weight per horsepower, computed on a basis of full load and of power in air of standard density unless otherwise stated.

PRESSURE NOZZLE.—The apparatus which, in combination with a gauge, is used to measure the pressure due to speed through the air. Includes both Pitot and Venturi tubes. Pressure nozzles of various types are also used in yawmeters and other instruments.

PROOFING.—Material applied to the fabric of an aerostat at the time of manufacture to protect it against weather or to prevent the passage of gas.

PROPELLER, PUSHER.—A propeller which is placed at the rear end of its shaft and pushes against the thrust bearing.

PROPELLER, TRACTOR.—A propeller which is placed at the forward end of its shaft and pulls on the thrust bearing.

PURITY OF A GAS.—The percentage, by number of molecules, of the light gas used for inflation, such as hydrogen, to all the gases within the container.

PUSHER AIRPLANE.—(*See* Airplane.)

PUSHER PROPELLER.—(*See* Propeller.)

QUADRUPLANE.—A form of airplane whose main supporting surface is divided into four parts, superimposed.

RACE ROTATION.—The rotation of the air influenced by a propeller. This rotation is much more marked in the slip stream than in front of the propeller.

RAKE.—The cutting away of the wing tip at an angle so that the main supporting surfaces seen from above will appear of trapezoidal form. The amount of rake is measured by the angle between the straight portion of the wing-tip outline and the plane of symmetry. The rake is positive when the trailing edge is longer than the leading edge.

RAKE, BLADE.—The angle which the line joining the centroids of the sections of a propeller blade makes with a plane perpendicular to the propeller shaft. The rake is positive when the blades are thrown forward.

RATE OF CLIMB.—The vertical component of the air speed of an aircraft; i. e., its vertical velocity with reference to the air.

RATE-OF-CLIMB INDICATOR.—An instrument indicating the vertical component of the velocity of an aircraft. Most rate-of-climb meters depend on the rate of change of the atmospheric pressure.

RELATIVE WIND.—The motion of the air with reference to a moving body. Its direction and velocity, therefore, are found by adding two vectors, one being the velocity of the air with reference to the earth, the other being equal and opposite to the velocity of the body with reference to the earth.

RESISTANCE DERIVATIVES.—Quantities expressing the variation of the forces and moments on aircraft due to disturbance of steady motion. They form the experimental basis of the theory of stability, and from them the periods and damping factors of aircraft can be calculated. In the general case there are 18 translatory and 18 rotary derivatives.

ROTARY.—Resistance derivatives expressing the variation of moments and forces due to small increases in the rotational velocities of the aircraft.

TRANSLATORY.—Resistance derivatives expressing the variation of moments and forces due to small increases in the translatory velocities of the aircraft.

REVERSE TURN.—A rapid maneuver to reverse the direction of flight of an airplane, made by a half loop and half roll in either sequence.

REVOLUTIONS, MAXIMUM.—The maximum number of revolutions per minute that may be maintained for periods not less than 5 minutes.

REVOLUTIONS, NORMAL.—The highest number of revolutions per minute that may be maintained for long periods.

RIB.—(*See* Wing rib.)

RIGGER.—One who is employed in assembling and aligning aircraft.

RIGGING.—The assembling and aligning of an aircraft.

RIGHT-HAND ENGINE.—An engine the final power delivery shaft of which rotates clockwise when viewed by an observer looking along the engine toward the power delivery end.

RIGHTING MOMENT.—A moment which tends to restore an aircraft to its previous attitude after any small rotational displacement.

RIGID AIRSHIP.—(*See* Airship.)

RIP CORD.—The rope running from the rip panel of a balloon or nonrigid airship to the basket, the pulling of which tears off the rip panel and causes immediate deflation.

RIP PANEL.—A strip in the upper part of a balloon or nonrigid airship which is torn off when immediate deflation is desired.

ROLL, ANGLE OF.—(*See* Angle.)

RUDDER.—A hinged or pivoted surface used for the purpose of impressing yawing moments on an aircraft; i. e., for controlling its direction of flight. (Fig. 10.)

RUDDER BAR.—The foot bar by means of which the rudder is operated.

RUDDER TORQUE.—The twisting effect exerted by the rudder on the fuselage, due to the relative displacement of the center of pressure of the rudder. The product of the rudder area by the distance from its center of area to the center line of the fuselage may be used as a relative measure of rudder torque.

SAFETY, FACTOR OF.—(*See* Factor of Safety.)

SAFETY LOOP.—A loop formed immediately outside the conical reversing bag through which the valve rope emerges from the bottom of an aerostat. Before the automatic valve can be opened by the aid of the valve rope the fastening of this safety loop is torn off by a strong pull on the valve rope from the nacelle.

SEAPLANE.—A particular form of airplane designed to rise from and land on the water.

BOAT SEAPLANE, OR FLYING BOAT.—A form of seaplane having for its central portion a boat which provides flotation. It is often provided with auxiliary floats or pontoons. (Fig. 14.)

FLOAT SEAPLANE.—A form of seaplane in which the landing gear consists of one or more floats or pontoons. (Fig. 15.)

SEMIRIGID AIRSHIP.—(*See* Airship.)

SERPENT.—A short, heavy trail rope.

SHOCK ABSORBER.—A spring or elastic member, designed to prevent the imposition of large accelerations on the fuselage, wings, and other heavy concentrated weights. Shock absorbers are usually interposed between the wheels, floats, or tail skid, and the remainder of the airplane to secure resiliency in landing and taxi-ing.

SHOCK-ABSORBER HYSTERESIS.—The ratio of the work absorbed in the shock absorber during one complete cycle to the total energy transmitted to the shock absorber during the first half of the cycle.

SHUTTERS.—The adjustable blinds or vanes which are used to control the amount of air flowing through the radiator and so to regulate the temperature of the cooling water.

SIDE SLIPPING.—Sliding with a component of velocity along the lateral axis which is inclined and in the direction of the lower end of that axis. When it occurs in connection with a turn it is the opposite of skidding (q. v.).

SKID FINS.—(*See* Fins.)

SKIDDING.—Sliding sidewise away from the center of curvature when turning. It is usually caused by banking insufficiently and is the opposite of side slipping (q. v.).

SKIDS.—Runners used as members of the landing gear and designed to aid the aircraft in landing or taxi-ing.

TAIL SKID.—A skid used to support the tail when in contact with the ground.

WING SKID.—A skid placed near the wing-tip and designed to protect the wing from contact with the ground.

SKIN FRICTION.—The tangential component of the fluid force at a point on a surface. It depends on the viscosity and density of the fluid, the total surface area and the roughness of the surface of the object.

SLIP.—The difference between the effective pitch and the mean geometrical pitch. Slip is usually expressed as a percentage of the mean geometrical pitch.

SLIP STREAM.—The stream of air behind a propeller.

SOAR, TO.—To fly without engine power and without loss of altitude. Lightly loaded gliders will soar in rising currents of air.

SOUNDING BALLOON.—(*See* Balloon.)

SPAN, OR SPREAD.—The maximum distance laterally from tip to tip of an airplane inclusive of ailerons, or the lateral dimension of an aerofoil.

SPAN, MEAN, OF A COMBINATION OF WINGS.—If $s$ be the mean span of the combination, $s_1$, $s_2$, and $s_3$, etc., the spans of each pair of wings separately corresponding to areas $S_1$, $S_2$, $S_3$, etc., then

$$s=\frac{s_1 S_1+s_2 S_2+s_3 S_3+ \quad . \quad . \quad . \quad .}{S_1+S_2+S_3+ \quad . \quad . \quad . \quad .}$$

SPEED:

AIR.—The speed of an aircraft relative to the air.

GROUND.—The horizontal component of the velocity of an aircraft relative to the earth.

SPEED, MINIMUM.—The lowest speed which can be maintained in level flight, with any throttle setting whatever.

SPEED, PITCH.—The product of the mean geometrical pitch by the number of revolutions of the propeller in unit time; i. e., the speed the aircraft would make if there were no slip.

SPIN.—An aerial maneuver consisting of a combination of roll and yaw, with the longitudinal axis of the airplane inclined steeply downward. The airplane descends in a helix of large pitch and very small radius, the upper side of the airplane being on the inside of the helix, and the angle of attack on the inner wing being maintained at an extremely large value.

SPINNER.—A fairing, usually made of sheet metal and roughly conical or paraboloid in form which is attached to the propeller boss and revolves with it.

SPIRAL INSTABILITY.—The instability on account of which an airplane tends to depart from straight flight, by a combination of side slipping and banking, the latter being always too great for the turn.

SPLICE (of a wooden member).—A joint of two or more pieces of wood in which one piece overlaps the other in such a manner as to maintain the strength.

SPREAD.—(*See* Span.)

STABILITY:

STATIC STABILITY.—A machine is statically stable if, when slightly displaced by rotation about its center of gravity (as in wind tunnel experimentation), moments come into play which tend to return the machine to its normal attitude.

DYNAMICAL STABILITY.—A machine is dynamically stable if, when displaced from steady motion in flight, it tends to return to that steady state of motion.

In a general way, the difference between static stability and dynamical stability is that the former depends on restoring moments and the latter on damping factors.

AUTOMATIC.—Stability dependent upon movable control surfaces. The term "automatic stability" is usually applied to those cases in which the control surfaces are automatically operated by mechanical means.

DIRECTIONAL.—Stability with reference to rotations about the normal axis; i. e., a machine possessing directional stability in its simplest form is one for which $N_v$ is negative. Owing to symmetry, directional stability is closely associated with lateral stability.

INHERENT.—Stability of an aircraft due solely to the disposition and arrangement of its fixed parts; i. e., that property which causes it, when disturbed, to return to its normal attitude of flight without the use of the controls or the interposition of any mechanical device.

LATERAL.—Stability with reference to disturbances involving rolling, yawing, or side-slipping; i. e., disturbances in which the position of the plane of symmetry of the aircraft is affected.

LONGITUDINAL.—Stability with reference to disturbances in the plane of symmetry; i. e., disturbances involving pitching and variations of the longitudinal and normal velocities.

STABILIZER.—(*See* Tail plane.)

STABILIZER, MECHANICAL.—A mechanical device to stabilize the motion of an aircraft. Includes gyroscopic stabilizers, pendulum stabilizers, inertia stabilizers, etc.

STABLE OSCILLATION.—(*See* Oscillation.)

STAGGER.—The amount of advance of the entering edge of an upper wing of a biplane, triplane, or multiplane over that of a lower, expressed as percentage of gap. It is considered positive when the upper wing is forward and is measured from the entering edge of the upper wing along its chord to the point of intersection of this chord with a line drawn perpendicular to the chord of the upper wing at the entering edge of the lower wing, all lines being drawn in a plane parallel to the plane of symmetry. (Fig. 11.)

STAGGER WIRES.—(*See* Wires.)

STALLING.—A term describing the condition of an airplane which from any cause has lost the relative air speed necessary for control.

STANDARD PITCH.—(*See* Pitch.)

STATIC THRUST.—The thrust developed by a propeller when the aircraft is held stationary on the ground.

STATION.—A term used to denote the location of framing attachment in a fuselage or nacelle (strut points in a trussed fuselage, bulkhead points in a veneer fuselage).

STATOSCOPE.—An instrument to detect the existence of minute changes of atmospheric pressure, and so of small vertical motions of an aircraft.

STAY.—A wire or other tension member; for example, the stays of the wing and body trussing.

STEP.—A break in the form of the bottom of a float or hull designed to assist in securing a dynamic reaction from the water.

STICK CONTROL.—(*See* Control stick.)

STRAND.—A species of wire made up of several individual wires twisted together. (There are usually 19 wires—a single wire as core, an inner layer of 6 wires, and an outer layer of 12.)

STREAMLINE.—The path of a small portion of a fluid, supposed continuous, commonly taken relative to a solid body with respect to which the fluid is moving. The term is commonly used only of such paths as are not eddying, but the distinction should be made clear by the context.

STREAMLINE FLOW.—The condition of continuous flow of a fluid, as distinguished from eddying flow.

STREAMLINE FORM.—A fair form intended to avoid eddying and to preserve streamline flow.

STRUT.—A member of a truss frame designed to carry compressive loads. For instance, the vertical members of the wing truss of a biplane (interplane struts) and the short vertical and horizontal member separating the longerons (q. v.) in the fuselage. (Figs. 1 and 12.)

STRUT, DRAG.—(*See* Drag strut.)

SURFACE.—An aerofoil used for sustentation or control or to increase stability. Applies to the whole member, and not to one side only.

BALANCED.—A surface, such as a rudder, aileron, etc., part of which is in front of its pivot.

SURFACE, MAIN SUPPORTING.—A pair of wings, extending on the same level from tip to tip of an airplane; i. e., a triplane has three main supporting surfaces. The main supporting surfaces do not include any surfaces intended primarily for control or stabilizing purposes.

SUSPENSION BAND.—The band around a balloon or airship to which are attached the main bridle suspensions of the basket or car.

SUSPENSION BAR.—The bar used for the concentration of basket suspension ropes in captive balloons.

SWEEP BACK.—The angle, measured in a plane parallel to the lateral axis and to the chord of the main planes, between the lateral axis of an airplane and the entering edge of the main planes. (Fig. 16.)

TAIL BOOM.—A spar or outrigger connecting the tail surfaces and main supporting surfaces Usually used on pushers. (Fig. 3.)

TAIL CUPS.—A steadying device attached by lines at the rear of certain types of elongated captive balloons. Somewhat similar to a sea anchor. (Fig. 17.)

TAIL DROOP.—A deformation of the airship in which the axis bends downward at the after end.

TAIL HEAVY.—The condition of an aircraft in which, in any given condition of normal flight the nose tends to rise if the longitudinal control is released; i. e., the condition in which the pilot has to exert a push on the control stick or column to maintain the given condition.

TAIL PLANE.—A stationary horizontal, or nearly horizontal, tail surface, used to stabilize the pitching motion. Often called "stabilizer." (Fig. 10.)

TAIL SETTING, ANGLE OF.—(*See* Angle.)

TAIL SKID.—(*See* Skids.)

TAIL SLIDE.—The rearward motion which certain airplanes may be made to take after having been brought into a stalling position.

TAIL UNIT.—The tail surfaces of an aircraft.

TANDEM AIRPLANE.—(*See* Airplane.)

TAXI, TO.—To run an airplane over the ground, or a seaplane on the surface of water, under its own power.

TOGGLE.—A short crossbar of wood or metal, having a shouldered groove, which is fitted at the end of a rope at right angles to it. It is used for obtaining a quickly detachable connection with an eye at the end of another rope. (Fig. 18.)

TRACTOR AIRPLANE.—(*See* Airplane.)

TRACTOR PROPELLER.—(*See* Propeller.)

TRAIL ROPE.—The long trailing rope attached to a spherical balloon, to serve as a brake and as a variable ballast.

TRAILING EDGE.—The rearmost edge of an aerofoil or propeller blade.

TRAJECTORY BAND.—A band of webbing carried in a curve over the top of the envelope of an airship to distribute the stresses due to the suspension. The use of trajectory bands was introduced in the Parseval airships. (Fig. 19.)

TRIPLANE.—A form of airplane whose main supporting surface is divided into three parts, superimposed.

TURN INDICATOR.—An instrument showing when the direction of the line of flight or the direction of the projection of that line on a horizontal plane is altering, and in its more refined forms, giving the rate of turn, in terms either of the angular velocity or of the radius of curvature.

UNSTABLE OSCILLATION.—(*See* Oscillation.)

USEFUL LOAD.—(*See* Load.)

VALVE, AUTOMATIC.—(*See* Automatic Valve.)

VENEER.—Thin sheets or strips of wood.

VENTURI TUBE.—A short tube with flaring ends and a constriction between them, so that, when fluid flows through it, there will be a suction produced in a side tube opening into the constricted throat. This tube, when combined with a Pitot tube or with one giving static pressure, forms a pressure nozzle, which may be used as an instrument to determine the speed of an aircraft through the air. (Fig. 21.)

VIRTUAL PITCH.—(*See* Pitch.)

WARP, TO.—To change the form of a wing by twisting it. Warping is sometimes used to maintain the lateral equilibrium of an airplane.

WASH.—The disturbance in the air produced by the passage of an aerofoil.

WASHIN.—A permanent increase in the angle of attack near the tip of the wing.

WASHOUT.—A permanent decrease in the angle of attack near the tip of the wing.

WEIGHT, DISCHARGEABLE.—(*See* Dischargeable Weight.)

WEIGHT, DRY.—(*See* Dry Weight.)

WEIGHT PER HORSEPOWER.—The dry weight of an engine divided by the normal horsepower developed at ground level.

WHEEL CONTROL.—(*See* Control Column.)

WIDTH RATIO, TOTAL (PROPELLER BLADE).—The product of blade width ratio by number of blades.

WIND, RELATIVE.—(*See* Relative Wind.)

WIND TUNNEL.—An elongated inclosed chamber, including means for the production of a substantially steady air current through the chamber. Models of aircraft or other objects are supported in the center of the airstream and their resistance and other characteristics when exposed to an air current of known velocity are determined. The term includes those laboratories in which, as in the Eiffel type, there is an experimental chamber of much larger cross-section than the air current.

WINDMILL.—A small air-driven turbine with blades similar to those of a propeller exposed on an aircraft, usually in the slip stream, and used to drive such auxiliary apparatus as gasoline pumps and radio generators.

WINDOW, INSPECTION.—(*See* Inspection window.)

WING.—The portion of a main supporting surface of an airplane on one side of the plane of symmetry; e. g., a biplane has four wings.

WING LOADING.—The weight carried per unit area of supporting surface. The area used in computing the wing loading should include the ailerons, but not the tail plane or elevators.

WING RESISTANCE. (*See* Drag.)

WING RIB.—A fore-and-aft member of the wing structure of an airplane, used to give the wing section its form and to transmit the load from the fabric to the spars. (Fig. 20.)

RIB, COMPRESSION.—A heavy rib designed to have the above functions and also to act as a strut opposing the pull of the wires in the internal drag truss. (Fig. 20.)

RIB, FORM.—An incomplete rib, frequently consisting only of a strip of wood extending from the leading edge to the front spar, which is used to assist in maintaining the form of the wing where the curvature of the aerofoil section is sharpest. (Fig. 20.)

WING SKID.—(*See* Skids.)

WING SPARS.—The principal transverse structural elements of the wing assembly of an airplane. The load is transmitted from the ribs to the spars, and thence to the lift and drag trusses. (Fig. 20.)

WING TRUSS.—The framing by which the wing loads of an airplane are transmitted to the fuselage; comprises struts, wires, or tie-rods, and spars.

WIRE.—In aeronautics refers specifically to hard-drawn solid wire.

WIRES, ANTIDRAG.—Wires designed primarily to resist forces acting parallel to the planes of the wings of an airplane and in the same direction as the direction of flight.

WIRES, ANTILIFT.—Wires in an airplane intended mainly to resist forces in the opposite direction to the lift, and to oppose the lift wires and prevent distortion of the structure by overtightening of those members.

WIRES, DRAG.—All wires designed primarily to resist forces acting parallel to the planes of the wings of an airplane and opposite to the direction of flight.

INTERNAL DRAG WIRES are concealed inside the wings.

EXTERNAL DRAG WIRES run from the wing cell to the nose of the fuselage or some other part of the machine.

WIRES, LIFT.—The wires which transmit the lift on the outer portion of the wings of an airplane in toward the fuselage or nacelle. These wires usually run from the top of an interplane strut to the bottom of the strut next nearer the fuselage.

WIRES, STAGGER.—Wires connecting the upper and lower surfaces of an airplane, and lying in planes substantially parallel to the plane of symmetry.

YAW, ANGLE OF.—(*See* Angle.)

YAWING.—Angular motion about the normal axis.

YAWMETER.—An instrument giving by direct reading the angle of yaw.

YOKE.—(*See* Control column.)

ZERO LIFT ANGLE.—The angle between the chord and the relative wind when the lift is zero.

ZERO LIFT LINE.—The position in the plane of an aerofoil section of the line of action of the resultant air force when the position of the section is such that the lift is zero.

ZOOM, TO.—To climb for a short time at an angle greater than that which can be maintained in steady flight, the machine being carried upward at the expense of its stored kinetic energy. This term is sometimes used by pilots to denote any sudden increase in the upward slope of the flight path.

# REPORT No. 91.

## NOMENCLATURE FOR AERONAUTICS.

By the National Advisory Committee for Aeronautics.

### PART III.

### AERONAUTICAL SYMBOLS.

| | Symbol. |
|---|---|
| Height | $h$ |
| Propeller diameter | $D$ |
| Angle of attack | $\alpha$ |
| $\mathrm{Tan}^{-1} D/L$ | $\gamma$ |
| Dihedral | $\Gamma$ |
| Angle of downwash | $\epsilon$ |
| Angle of tail setting | $\beta$ |
| Propeller helix angle | $\phi$ |
| True air speed | $V$ |
| Indicated air speed | $V_i$ |
| Lift | $L$ |
| Drag | $D$ |
| Cross-wind force | $C$ |
| Longitudinal force | $X$ |
| Lateral force | $Y$ |
| Normal force | $Z$ |
| Rolling moment | $L$ |
| Pitching moment | $M$ |
| Yawing moment | $N$ |
| NOTE.—In dealing with stability theory, $X$, $Y$, $Z$, $L$, $M$, and $N$ are commonly referred to the forces and moments per unit mass. | |
| Propeller thrust | $T$ |
| Propeller torque | $Q$ |
| Power | $P$ |
| Mass of machine $=\frac{W}{g}$ | $m$ |
| Total weight | $W$ |
| Propeller efficiency | $\pi$ |

| | Symbol. |
|---|---|
| Air density (mass per unit volume) | $\rho$ |
| Kinematic viscosity | $\upsilon$ |
| Area | $S$ |
| Angle of yaw | $\Psi$ |
| Angle of pitch | $\theta$ |
| Angle of roll | $\phi$ |
| Component of velocity parallel to the $X$-axis and relative to the undisturbed air | $u$ |
| Component of velocity parallel to the $Y$-axis and relative to the undisturbed air | $v$ |
| Component of velocity parallel to the $Z$-axis and relative to the undisturbed air | $w$ |
| Angular velocity of roll | $p$ |
| Angular velocity of pitch | $q$ |
| Angular velocity of yaw | $r$ |
| Moments of inertia about the $X$, $Y$, and $Z$ axes, respectively | $A$, $B$, $C$ |
| Products of inertia with respect to the $Y$ and $Z$, $X$ and $Z$, and $X$ and $Y$ axes, respectively | $D$, $E$, $F$ |
| Radii of gyration about the $X$, $Y$, and $Z$ axes, respectively | $K_A$, $K_B$, $K_C$ |
| Logarithmic increment or decrement of amplitude. $(\theta=\theta_0 e^{-\lambda t})$ | $\lambda$ |

### COEFFICIENTS.

Coefficients of forces and moments ("absolute" coefficients to be used in all cases):

$L_c$, $D_c$, $C_c$, $X_c$, $Y_c$, $Z_c$, $L_c$, $M_c$, $N_c$.

Propeller thrust coefficients:

$$T_c=\frac{T}{\rho N^2 D^4},\quad T_c'=\frac{T}{\rho V^2 D^2},\quad T_c''=\frac{T}{\rho \frac{V^4}{N^2}};$$

where N = Revolutions per minute.

Propeller torque coefficients:

$$Q_c=\frac{Q}{\rho N^2 D^5},\quad Q_c'=\frac{Q}{\rho V^2 D^3},\quad Q_c''=\frac{Q}{\rho \frac{V^5}{N^3}}.$$

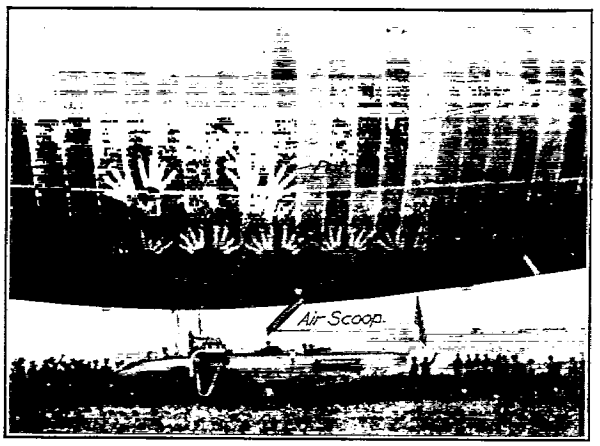



FIG. 2.

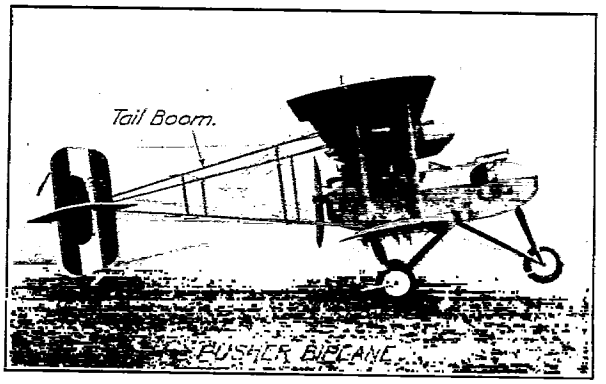



FIG. 3.

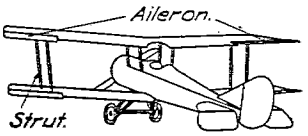
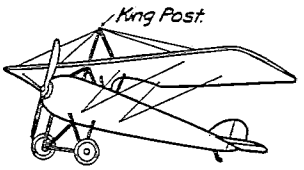



FIG. 1.




TRACTOR MONOPLANE.

FIG. 4.

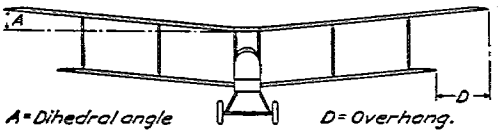



FIG. 5.

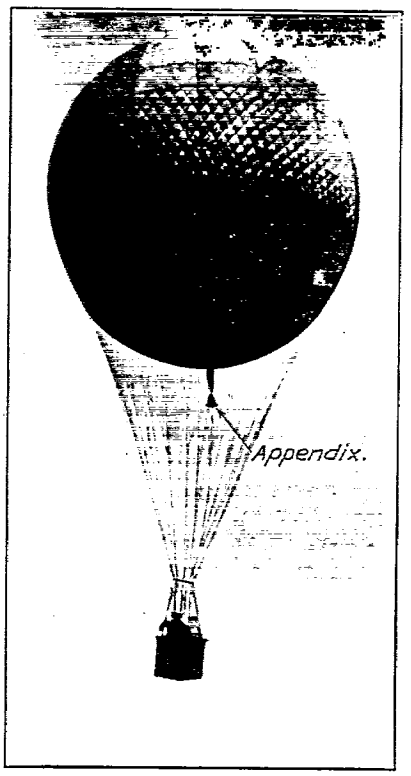
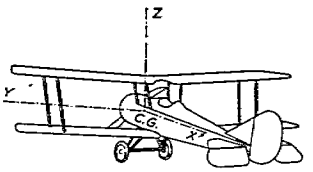



FIG. 6.




Axes of an Airplane.

FIG. 7

FIG. 8.

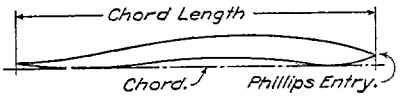



FIG. 9.

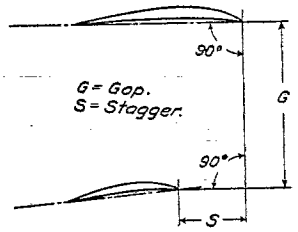



FIG. 11.

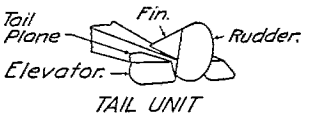



FIG. 10.

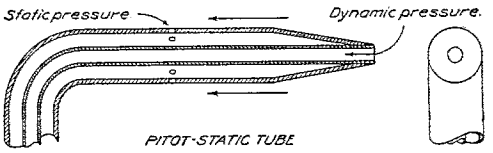



FIG. 13.

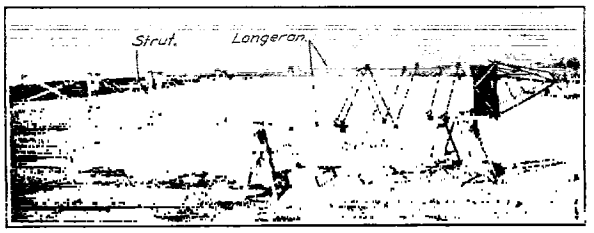



FIG. 12.

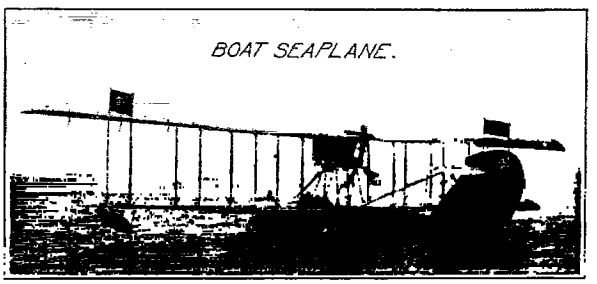



FIG. 14.

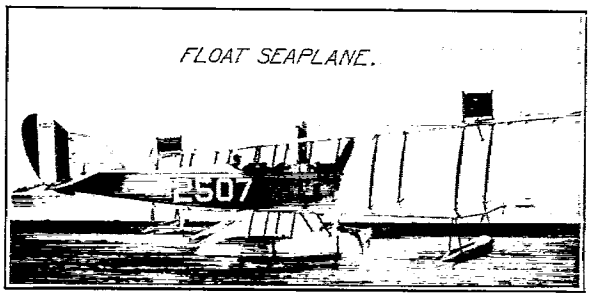



FIG. 15.

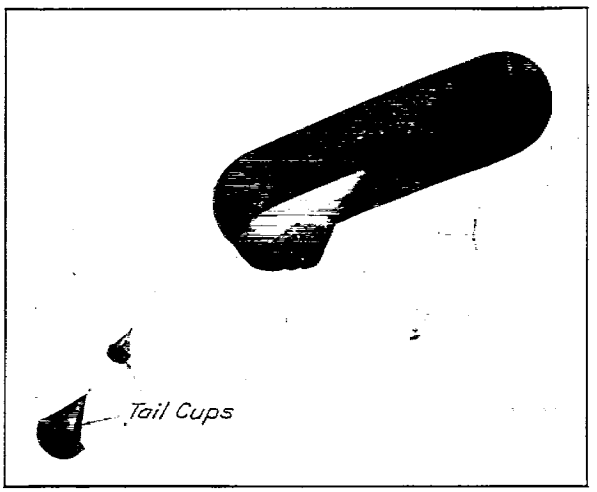



FIG. 17.

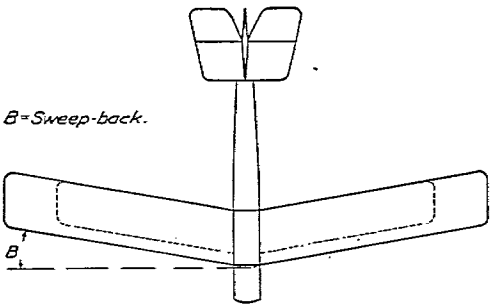



FIG. 16

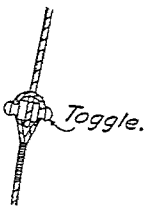



FIG. 18.

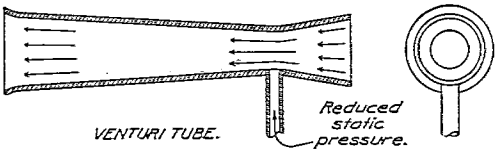



FIG. 21.

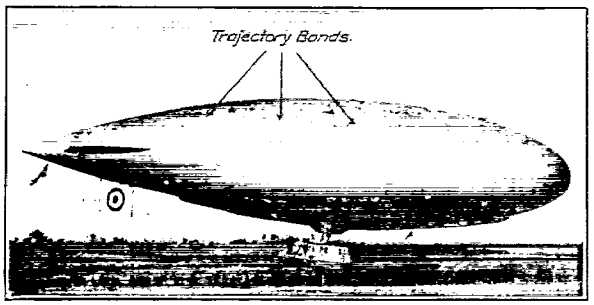



FIG. 19.

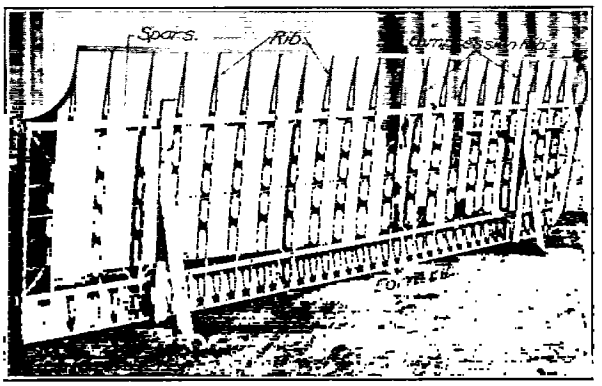



FIG. 20.

Propeller power coefficients:

$$P_c=\frac{P}{\rho N^3 D^5},\quad P_c'=\frac{P}{\rho V^3 D^2},\quad P_c''=\frac{P}{\rho \frac{V^5}{N^2}},\quad P_c'''=\frac{P}{\rho V N^2 D^4}.$$

DERIVATIVES.

$\left.\begin{matrix} X_u & Z_u & M_u \\ X_w & Z_w & M_w \\ X_q & Z_q & M_q \end{matrix}\right\}$ Symmetric resistance derivatives.

$\left.\begin{matrix} Y_v & L_v & N_v \\ Y_p & L_p & N_p \\ Y_r & L_r & N_r \end{matrix}\right\}$ Asymmetric resistance derivatives.

$\left.\begin{matrix} Y_u & L_u & N_u \\ Y_w & L_w & N_w \\ Y_q & L_q & N_q \end{matrix}\right\}$ Combined resistance derivatives which disappear in a symmetrical aircraft.

$\left.\begin{matrix} X_v & Z_v & M_v \\ X_p & Z_p & M_p \\ X_r & Z_r & M_r \end{matrix}\right\}$ Combined resistance derivatives which do not disappear but are generally neglected.